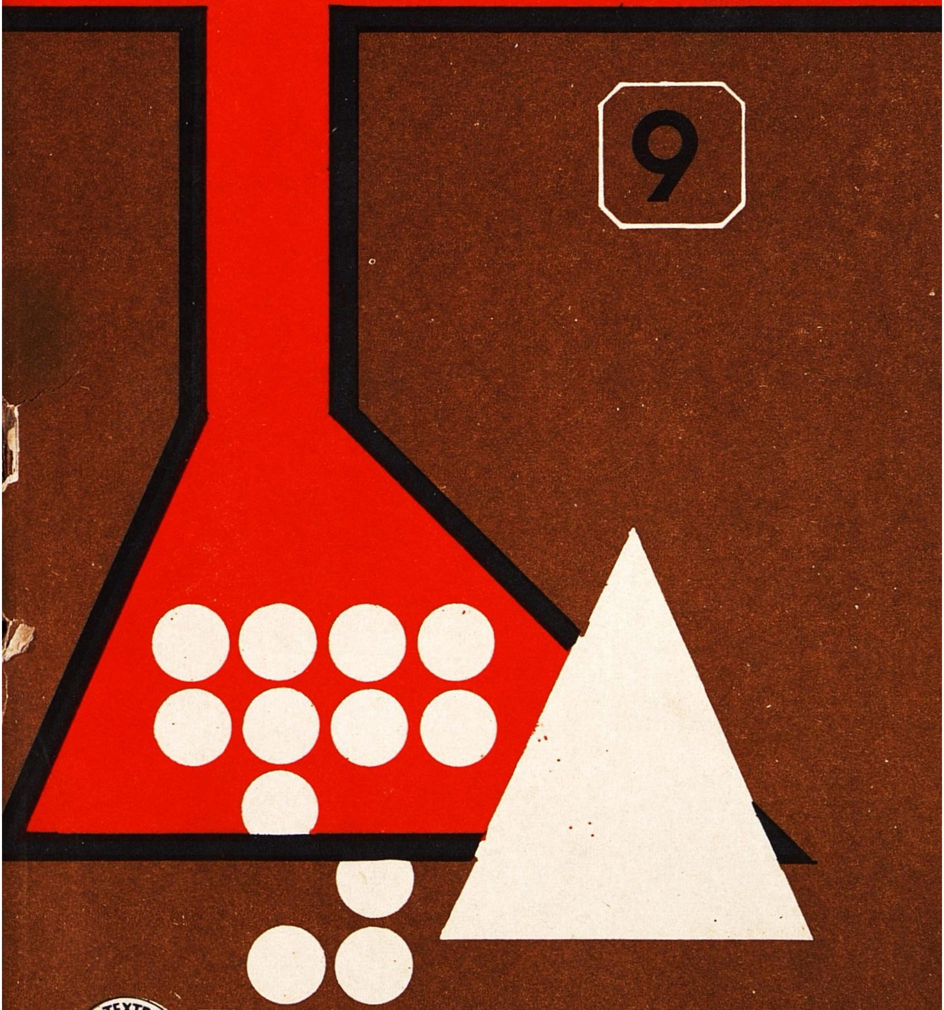
SCIENCE



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Tamil Nadu Textbook Society

SCIENCE

STANDARD IX

Untouchability is a sin
Untouchability is a crime
Untouchability is inhuman

Tamil Nadu Textbook Society
Madras

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Part A - Physics

I. Mechanics

1. ACCELERATED MOVEMENTS

It is a well known fact that a car moving down a slope speeds up as time passes by. The velocity of the car goes on increasing. So also a car (pushed) going up a slope slows down gradually as time passes by. The velocity of the car decreases. In all these cases, we see that the increase or decrease in speed is gradual and does not take place all of a sudden. All motions around us are not constant, they either change in quantum or change in direction. Motions which result in the change of direction or change of magnitude of velocity of a body are termed accelerated motions. This may be increase in velocity called acceleration or decrease in velocity called deceleration or negative acceleration or retardation.

Definition of Acceleration

The change of velocity of a moving particle in one second (rate of change of velocity) is called acceleration.

Signs of Acceleration

A particle moving from rest always gains velocity and hence is accelerated. A freely falling body is also accelerated. The moving particle under an opposing force always loses velocity and hence decelerated. Bodies thrown upward are always decelerated. Acceleration is denoted by the (+) plus or positive sign and deceleration is denoted by the (—) minus sign or negative sign.

Units of Acceleration

We denote every physical quantity with a certain unit. Mass is denoted by grammes or kilogrammes unit. Length

is denoted by cm. or km. and time is denoted by seconds. Velocity is represented by *cm/sec* or *m/sec*. How will you represent acceleration?

Acceleration is the rate of change of velocity and hence it is denoted by *cm/sec/sec.* or cm/sec^2 or m/sec^2 or $ms.^{-2}$

Uniform Acceleration

If the rate of change of velocity is equal in equal intervals of time, however small the intervals may be, the particle is said to have a uniform acceleration.

Equation for Acceleration

Let us consider a particle moving with a uniform velocity of 'u' m/sec. This velocity changes to 'v' m/sec in time 't' seconds. Therefore the change in velocity of the particle is $v - u$ and this change takes place in 't' seconds. Hence the rate of change of velocity is $\frac{v-u}{t}$. This is called acceleration.

If 'a' is the acceleration, then $a = \frac{v-u}{t}$ m/sec^2

Equation for Motion

Consider a particle moving with uniform acceleration in a straight line. Let the initial velocity of the particle be u m/sec. Let this velocity be changed to 'v' m/sec. in a time 't' seconds.

$\therefore$ Change in velocity in t seconds $= v - u$

$\therefore$ Rate of change of velocity $= \frac{v-u}{t}$.

By definition, acceleration is rate of change of velocity.

$\therefore$ Acceleration $a = \frac{v-u}{t}$.

$\therefore v - u = at$

$\therefore \quad v = u + at$

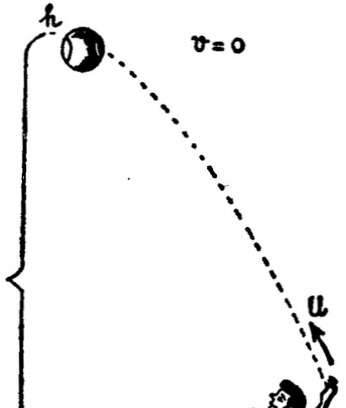
$$\boxed{v = u + at}$$

Acceleration due to gravity

Any body falling to earth from the sky gets accelerated, due to the pull of the earth. The acceleration resulting from the pull of the earth is known as acceleration due to gravity.

Acceleration due to gravity is not the same at all points on the surface of the earth. It varies from polar regions to the equatorial regions. Acceleration due to gravity is greater in polar regions than in equatorial regions. Acceleration due to gravity is represented by the letter 'g'. The average acceleration due to gravity on earth is 980 cm./sec^2. or 9·8 m/sec.^{2}

The maximum height reached by a ball thrown upward



The maximum height attained by a ball thrown upwards
Fig. 1

If a ball is thrown upwards in the sky, it generally loses its velocity. In other words it is decelerated. When it reaches the maximum height it could attain in a given time, its velocity becomes zero. The ball initially moves with a velocity of u m/sec. When it reaches the maximum height 'h', its velocity 'v' is equal to zero.

According to the equation of motion $v^2 = u^2 + 2ah$. But here the ball is retarded by the gravitational pull of the earth and so the equation becomes $v^2 = u^2 - 2gh$. The negative sign indicates the deceleration of the stone.

$$0^2 = u^2 - 2gh$$

$$\therefore 2gh = u^2$$

$$\therefore h = \frac{u^2}{2g}$$

The maximum height reached by the ball $h = \frac{u^2}{2g}$.

What do you understand from this? The acceleration due to gravity is unaltered at a particular place and so the maximum height reached is dependent only on the initial velocity given to the ball.

The time taken by the ball to reach the maximum height

According to the equation of motion, $v = u + at$. In this case, the acceleration $a = -g$ and hence $v = u - gt$. When the ball is at its maximum height, the final velocity is zero. (i.e) $v = 0$. So, $0 = u - gt$ or $gt = u$. from which we get $t = \frac{u}{g}$.

Time taken to reach the maximum height $t = \frac{u}{g}$

For your consideration

All particles, big or small, fall to the earth when allowed to fall freely. All of them are subjected to the same acceleration due to gravity at a place. Hence which of the two — a big body or a small body will have greater velocity?

At a glance you may be tempted to say that the bigger body will have greater velocity. But the answer is wrong. All the particles, big or small, fall with the same velocity and they also take equal time to fall. This was proved by Galileo, a great *Italian* philosopher in his famous experiment called 'the feather and the guinea experiment.'

For Thought

The gravitational pull of the moon is less than that of the earth. What will be the acceleration of particles in the moon? In fact the gravitational pull of moon is 1/6 of that of the earth. To what height should a particle be thrown up in the sky of the moon if it is given a particular initial velocity?

Questions

1. What is meant by accelerated motion?

2. Define acceleration.

3. What signs are made use of to denote acceleration and retardation?

4. Write down the unit of acceleration.

5. Why should the unit of acceleration be notified in sec^2 units?

6. Define uniform acceleration.

7. Deduce the formula $a=\frac{v-u}{t}$.

8. Show that $v=u+at$.

9. A particle moves with an initial velocity of 5 m/sec This velocity changes to 8 m/sec. in 10 seconds. Calculate the acceleration.

10. A car moving with a uniform speed of 15 m/sec, is uniformly accelerated at the rate of 2 m/sec^2. Calculate its speed after 2·5 seconds.

11. Define acceleration due to gravity.

12. A stone is thrown upwards. When will it be accelerated and when will it be decelerated?

13. Write down the average value of the acceleration due to gravity.

14. Why does the acceleration due to gravity vary from place to place?

15. Can all motions of the planets round the sun be termed as accelerated motions? Are they uniformly accelerated motions?

16. Which will reach the ground first? a heavy ball or a light ball when allowed to fall freely from a height.

17. Deduce the formula to calculate the maximum height reached by a stone thrown upwards.

18. Deduce the formula to calculate the time taken by a body thrown upwards to reach its maximum height.

19. The acceleration due to gravity acting on a body, irrespective of its size or mass, is the same. Who said this?

20. Fill in the blanks

(a) Motions which result in ________ are termed as ________ motions.

(b) The change in velocity in one second of a moving particle is called ________.

(c) Accelerated motions are denoted by ________ and decelerated motions are denoted by ________.

(d) The unit of acceleration is ______

(e) If the acceleration of a particle is equal in equal intervals of time it is called ________.

(f) $v = \text{—} + a\text{—}$

21. Will the stone thrown upwards take the same time to come down as to what it took to reach the maximum height?

2. MOMENTUM

Place a glass plate on the table, and carefully place a big-stone on it. Observe what happens. Take a very small stone and hold it at a distance from the glass plate and drop it on the plate. Observe what happens. In the first case, if carefully done, the glass plate withstands the weight of the stone. But in the second case, the tiny stone falling on the glass plate breaks it into pieces. Why?

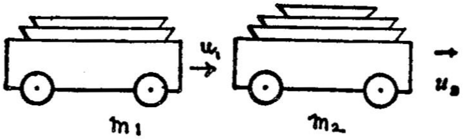
Keep a piece of nail on the table and place a heavy hammer over its head. Observe what happens. Then strike the nail with the hammer. The nail is driven into the table. Why?

Watch carefully a lizard or any insect falling to the ground from the ceiling. No sooner do they touch the ground than they crawl back to the ceiling. But what will happen if one of us fall from the ceiling to the ground? Will not our bones break and make us immobile?

Then again watch the cycle, car or a lorry in collision with another body. The damage caused by the impact of the lorry is greater than the damage due to the car or the cycle. Why?

In our daily life we watch situations of similar kind. Objects in motion acquire a characteristic property which depend on their mass and velocity. It is called the **momentum** of the object. It is the product of the mass and velocity. If the mass of the object is 'm' and if it moves with a velocity 'v' the momentum of the object $M = m \times v$.

Conservation of Momentum



Bodies in motion before impact
Fig. 2

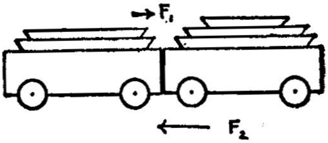
Let us consider the momentum of two bodies under collision. This can be done through several experiments. In

Fig. 2, two trolleys are shown moving. We can study the momentum of these trolleys by making them collide.

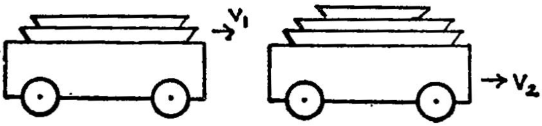
The mass of the first trolley is m_1 and it moves with a velocity u_1. So the momentum of this trolley is $m_1 \times u_1$.

The mass of the second trolley is m_2 and its velocity is u_2. Therefore the momentum of the trolley is $m_2 \times u_2$. The total momentum of these two trolleys before impact is $m_1u_1 + m_2u_2$.

Let us consider the momentum of the trolleys in collision. They are in contact for t seconds and during that time the force due to trolley_1 is given to the trolley_2 and the force due to trolley_2 is given to trolley_1. Because of the impact and the exchange of forces, the trolleys move with different velocities after the impact.



Bodies in motion during impact
Fig. 3



Bodies in motion after impact
Fig. 4

The first trolley moves with a velocity v_1 and the second trolley moves with a velocity v_2. Their momentum are m_1v_1 and m_2v_2. Therefore total momentum after the impact is $m_1v_1 + m_2v_2$.

According to Newton's second law of motion $F = m \times a$. *(i. e.)* Force = mass × acceleration.

$$= \text{mass} \times \frac{\text{change in velocity}}{\text{time}}$$

Therefore force due to trolley_1 given to trolley_2 is F_1.

$$F_1 = m_2 \frac{v_2 - u_2}{t}$$

Force due to trolley$_2$ given to the trolley$_1$ is F_2

$$F_2 = m_1 \frac{v_1 - u_1}{t}$$

By Newton's third law of motion,

$$F_1 = - F_2$$

$$\therefore m_2 \frac{(v_2 - u_2)}{t} = - m_1 \frac{(v_1 - u_1)}{t}$$

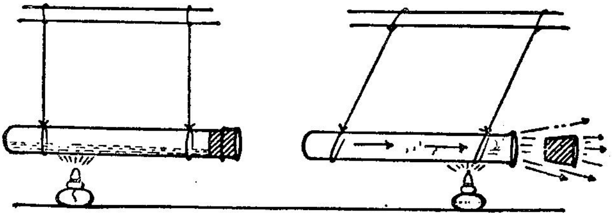
$$\therefore m_2 v_2 - m_2 u_2 = - m_1 v_1 + m_1 u_1.$$

$$\therefore m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2.$$

That is when two bodies collide with each other, the total momentum after impact is equal to the total momentum before impact. This is called the law of conservation of momentum.

What do we understand from the conservation of momentum?

We will be able to explain many of the phenomena that take place around us in our daily life. Let us try the following experiment: Take some water in a hard test-tube



Test tube responding to the reaction of the steam pressure
Fig. 5

and close its mouth with a cork. Hang it from a retort stand horizontally by two threads. Gently heat the test tube. What do you observe? The water in the tube begins to boil. Observe what happens. In a couple of minutes, sufficient steam pressure is generated in the test tube and the cork flies out in one direction while the test tube itself moves in the opposite direction. Can you explain this?

The cork was driven out of the test tube by the force of the steam that got accumulated in it. The force which deflected the test tube is also the same steam pressure. Both motions are caused under the action of one and the same force. Does it not look strange? Really what happened was that the cork which was forced out by the steam pressure reacted to it. In turn, the cork exerted an equal and opposite force on the steam which in turn transmitted the force to the test tube to which it is in contact with. The test tube having been hung by threads is pushed back resulting in its movement.

A similar thing happens when a rifle is fired. While the bullet flies fast outside the gun, the rifle itself is subjected to a slight movement backward. This is known as the recoil of the gun.

One may wonder how one and the same force really leads to such dissimilar effects. The bullet flies far away and the gun moves only slightly backward due to same force. This phenomenon can definitely happen because the acceleration produced in a body is inversely proportional to the mass of the body. Hence the bullet being small in mass moves very far while the gun with a heavy mass moves only a little.

Recoil of the Gun

Let us consider the mass of the gun as M kg and initially there is no velocity to it. The bullet of mass m kg in the gun has also no velocity in the beginning. Hence the momentum of both the gun and the bullet initially is zero.

But when the gun is fired, the bullet moves with a velocity of V m/sec while the gun moves a little with a velocity of v m/sec. The total momentum of both the gun and the bullet after firing is $Mv + mV$. According to the law of conservation of momentum, momentum after impact is equal to the momentum before impact.

$$Mv + mV = O$$

or $$mV = -Mv$$

Hence from this we understand that when the bullet moves out in one direction, the gun moves in the opposite direction.

which is indicated in the above expression by the negative sign.

Loss of Kinetic Energy due to Impact

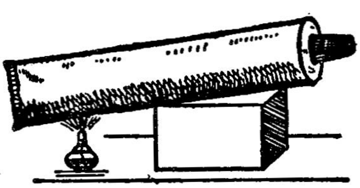
When two objects in motion collide, their total momentum remains unchanged. The kinetic energy of the system suffers a loss. The loss is effected in the generation of heat after the impact or twisting of the objects out of shape or damaging the roads and so on.

Questions

1. On what factor does the momentum of a particle depend?
2. How will you calculate the momentum of a body?
3. Why is that the damage caused by the impact of an engine is greater than that of a cycle with the same velocity?
4. State the law of conservation of momentum.
5. How will you verify the law of conservation of momentum?
6. Why does the gun recoil?

Do it Yourself

Collect an empty toothpaste tube and fill it with a little quantity of water. Support it slantingly in such a way that it can move freely. Heat the tube from underneath and observe what happens. Discuss the result with your teacher.

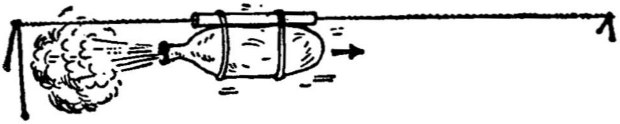


Empty toothpaste tube partly filled with water

Fig. 6

Tie an air filled balloon to a small glass tube and slide it across the thread tied to two poles kept apart. Unite the

mouth of the balloon and observe what happens. How will you explain the movement of the balloon?



Balloon in motion under force of escaping air

Fig. 7

II. Fluids

3. LIQUIDS

Liquids and gases are called fluids because of their fluidity in nature. We use vessels to store the fluids. We feel the impact of the molecules of the fluids in a container on its sides. How?

If we have a container with thin sides or flexible sides, the liquid inside the container makes its sides to bulge out. If a cork is pushed into the liquid, we exactly feel the upward force of the liquid. Hence we understand that a liquid exerts its force on all the sides of the container. We can measure the force exerted by a liquid.

The total weight of the liquid acts on the total surface area of the bottom of the container in which it is held. The force due to this weight of the liquid, in a container on its bottom surface is called the **thrust**. If the same force is calculated on unit area it is called the **pressure.**

Calculation of Thrust

Let us assume that A cm^2. is the area of the bottom of the container having a liquid to a height of h cm. If the density

of the liquid is d gm/cm^3, then the weight of the liquid acting on the bottom surface of the container can be calculated thus:

$$\text{volume of the liquid} = \text{area} \times \text{height of the liquid}$$
$$= Ah \text{ cm}^3$$
$$\text{mass of the liquid} = \text{volume} \times \text{density}$$
$$= Ah \text{ cm}^3 \times d \text{ gm/cm}^3 = Ahd \text{ gm.}$$

If T is the thrust of the liquid acting on the bottom surface

$$T = Ahd \text{ gm.}$$

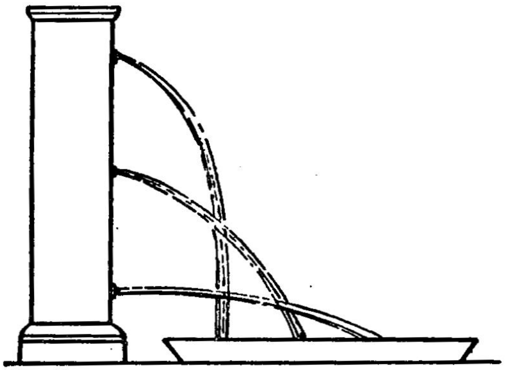
Calculation of the Pressure of the Liquid

According to the definition of the thrust, it is the weight of the liquid acting on the total surface of the bottom of the container and pressure is the weight acting on an unit area. Hence $T = Ahd$ gm. It is acting on a total surface area of A cm^2. Therefore force on unit area $= Ahd/A$ or hd gm/cm^2 If P is the pressure of the liquid then $P = hd$ gm/cm^2

Relationship between Thrust and Pressure

$T = Ahd$ gm. and $P = hd$ gm/cm^2 Therefore $P = T/A$. That is pressure = thrust/area.

Pressure of the Liquid depends on the Depth



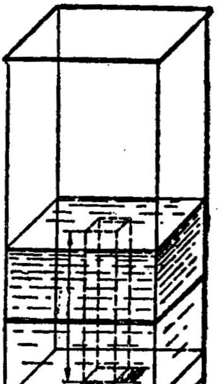
Sideward thrust of a liquid varying with depth.
Fig. 8

Consider a point inside a liquid. As it remains at rest it is evident that the pressure of the point on all its sides are

equal. If it is not so the point inside the liquid would move in any one of the directions in which the force acting on it is not balanced.

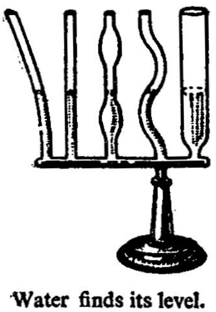
Take a tall cylindrical tin can and make holes one below the other in a vertical line. Fill the can with liquid and observe what happens. Liquid gushes out of the tin can from all the holes but with varying forces. The force at the top most hole is the least and the force at the bottom most hole is the largest. From this we understand that the pressure of the liquid increases with depth.

Consider a vessel of 1 cm^2. base. Pour into it 1 kg. of water and mark the level of water in the vessel. The pressure of the liquid at the bottom is 1 kg/cm^2. Now pour another kg. of water into the same vessel and note the level of water. It has increased. The pressure this time at the bottom is 2 kg/cm^2 It also shows that the pressure of a liquid increases with depth.



Liquid in a vessel
Fig. 9

The pressure of the liquid is independent of the shape of the vessel

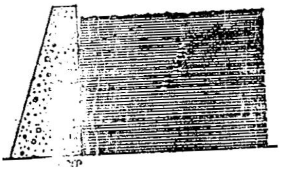


Water finds its level.
Fig. 10

Look at the type of the vessel shown in Fig. 10. The vessel has different portions of different shapes and cross sectional area. They are all connected by a common tube closed at both the ends. Pour water into any one of the portions ofthe vessel and observe what happens. The water level becomes the same in all the portions of the vessel irrespective of the shape. The pressure of the liquid in all the portions is the same though the cross sectional area differs.

Questions

1. What are fluids?
2. Give two examples for fluids.
3. How will you show that fluids exert a force on the sides of the container?
4. How will you show that fluids have upward thrust?
5. Define thrust.
6. Write the unit of thrust.
7. Define pressure.
8. What is the unit of pressure?
9. Show that the pressure increases with depth.
10. How will you calculate the thrust of a liquid in a container?
11. How will you calculate the pressure of a liquid?
12. A container of 10 cm^2. base contains water to a depth of 15 cm. Calculate the thrust of the liquid at the bottom of the vessel.
13. A cylindrical vessel of 10 cm. radius contains a liquid of density 0·8 gm/cm^3 to a height of 21 cm. Calculate the thrust and the pressure of the liquid.



Shape of a dam
Fig. 11

14. Show that the pressure of the liquid is independent of the shape of the vessel.
15. Why should the base of the dam be broader than the top?
16. Deduce the relationship between thrust and pressure.
17. A tall vessel contains mercury to a depth 5 cm. and a liquid of 0·75 density stands to a height of 10 cm.

over the mercury. The density of mercury is $13{\cdot}6\ gm/cm^3$. Calculate the thrust and pressure exerted by both the liquids at the bottom of the vessel (Area of the bottom is 1·25 sq. cm).

18. A liquid exerts a thrust of 1200 gm. on a surface area of $120\ cm^2$. What is the pressure of the liquid ?

19. Why should an air bubble grow in size as it rises to the surface of a liquid ?

20. What contrivance is made use of by deep sea divers to protect themselves from the pressure of the sea water at the bottom ?

21. Fill in the blanks

(a) Air and water are called ————.

(b) Cork and wood ———— on water due to the ———— thrust of water.

(c) As we go deep into the water its ———— increases.

(d) Pressure depends upon ————, ———— while thrust depends upon ————, ———— ————.

(e) A liquid will rise to ———— in containers of different shapes and sizes which are connected internally.

(f) Partially filled ballon will ———— in volume while it rises in the sky.

4. BALANCING COLUMNS

U - TUBE

How do you buy your vegetables? To get a kg of vegetable the man puts one kg weight in one of the pans of the balance and balances it with the vegetable you want. If the two pans of the balance are steady, we take it that the weight of the vegetable is equal to the weight of 1 kg. How do you buy a metre of cloth for your use? The man measures exactly the length of a metre scale of the cloth you want and

gives it to you. We take it to be one metre because it is equal in length to the metre scale. Hence for all purchases we have standard scales with which we compare the weight or length.

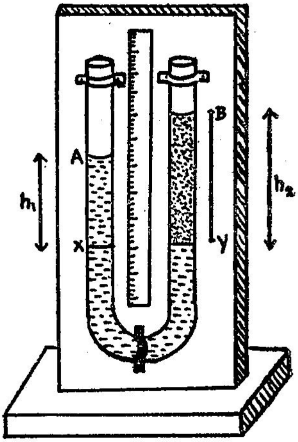
Likewise to find the specific gravity of a liquid, we can make use of a liquid of known density to compare with.

Usually we use water whose density is 1 gm/cm³. If two liquids of different specific gravities balance each other in a system, that system is called the balancing column of liquids.

To find the specific gravity or the relative density as it is otherwise called, by the method of balancing columns there are two types of apparatus available. One is called the *U* tube and the other is known as the Hare's apparatus.

U Tube

It is a transparent tube in the shape of the letter 'U' fixed to a wooden support. It is made to stand erect on the table. A scale is also fixed in between the limbs of the *U* tube, from which the readings of the levels of liquids in the limbs can be read easily.

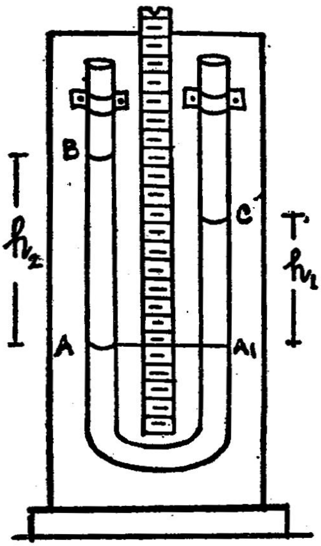


'*U*' Tube-Immiscible Liquid
Fig. 12

How to use a U Tube

The *U* tube can be conveniently made use of to find the specific gravity of liquids which are immiscible in water. It is not convenient to find the specific gravity of liquids which freely mix with water. Even that could be overcome if we make use of another liquid, say mercury, which will not react with the liquid whose specific gravity has to be measured.

To determine the specific gravity of the liquid



Determination of specific gravity of a liquid in a '*U*' tube
Fig. 13

Fig. 13 shows kerosene and water balancing each other in a *U* tube. As kerosene is immiscible with water, it stands out as a separate layer with a common surface in contact with water. Let us mark this surface as AA_1. Above this common level stands distinctly the kerosene level as AB and water level as A_1C. Let us suppose that the density of water be d_1 and that of kerosene be d_2. Let the height of the water column A_1C be h_1 cm. and the height of the kerosene column AB be h_2 cm. Then the pressure exerted by the water column at AA_1 line is $h_1 d_1$ gm/cm² and the pressure exerted by kerosene on the same line is $h_2 d_2$ gm/cm². As the two points lie on the same horizontal line AA_1 the pressure due to water column and the pressure due to liquid column are equal.

The pressure at A_1 = the pressure at A

Pressure due to water = pressure due to liquid.

$$h_1 d_1 = h_2 d_2$$

$$\text{or } \frac{d_2}{d_1} = \frac{h_1}{h_2}$$

$$d_1 = 1 \therefore d_2 = \frac{h_1}{h_2}$$

d_2/d_1 is called the specific gravity of the liquid. (Here it is kerosene). Therefore specific gravity of any liquid is given by the formula h_1/h_2.

Specific gravity of the given liquid $= \frac{\text{Height of water column}}{\text{Height of liquid column.}}$

Experiment to find the Specific Gravity of a Liquid.

Keep a clean *U* tube vertically on a table. Using a funnel introduce water in one of the limbs of the *U* tube. Remove air bubbles if any. Using a different funnel, pour one c.c. of the given liquid, in the other limb of the tube. Let the liquids adjust themselves and after they settle down mark the common level. Note down the levels of water and the liquid in the upper part of the *U* tube. Repeat the experiment several times each time adding more of the given liquid in the same limb. Tabulate the readings and calculate the heights of the water column 'h_1' and the liquid column 'h_2' Divide the height of water column by the height of liquid column. The quotient is the specific gravity of the liquid.

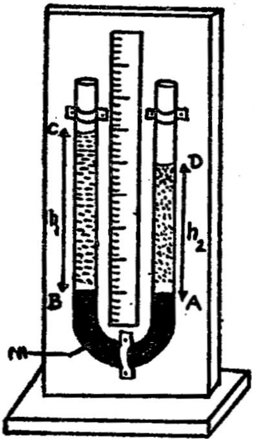
Ex. No.	Common Level A	Upper Level of Water C	Height of Water Column. $C-A=h_1$	Upper level of liquid B	Height of liquid Column. $B-A=h_2$	Sp. Gr. of liquid $\frac{h_1}{h_2}$

Average specific gravity

To find the specific gravity of a liquid that mixes with water using the *U* tube.

The entire bottom curved portion of the *U* tube is filled with a third liquid—in this case with mercury. Then water is poured into one of the limbs of the *U* tube and the given liquid is poured in the other limb, such that the mercury levels in both the limbs remain the same. In that case the height of water column at one end of the mercury will balance the

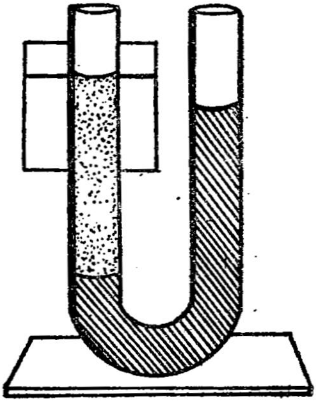
height of the liquid column, at the other end of the mercury. By measuring the heights of water and the liquid columns, the specific gravity of the miscible liquid can be calculated.



Determination of Specific gravity of liquids mixing with Water
Fig. 14

Points to note while doing the U Tube Experiment.

1. The apparatus must be vertical.
2. Air bubbles, if any, should be removed.
3. Readings have to be noted without any parallax error.
4. Separate funnels should be used for each liquid.
5. The same limb should be used for the liquids when the experiment is repeated.
6. Always pour the heavier liquid first into the apparatus.
7. If the liquids are miscible, a third liquid that will not react with the given liquid should be taken in the apparatus.
8. When a third liquid is made use of, care should be taken to see that the levels of the third liquid in both the limbs are equal at all times.



To avoid Parallax Error
Fig. 15

Questions

1. What do you mean by the balancing column of liquids?
2. Draw a neat sketch of the *U* tube.
3. Write a short note on *U* tube.

4. For what type of liquids, is the *U* tube easily made use of to find the specific gravity?

5. If a liquid miscible with water is given, can you find the specific gravity with the *U* tube? How?

6. Explain the experiment to find the specific gravity of kerosene using a *U* tube.

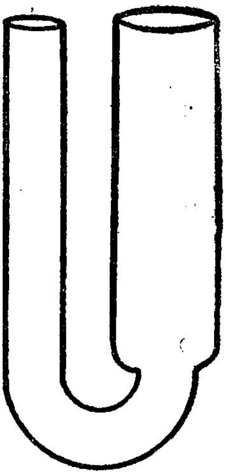
7. Give the tabulation used for the *U* tube in determining the specific gravity.

8. Deduce the formula for finding the specific gravity of a liquid using the *U* tube.

9. What are the points to remember while doing the experiment in the *U* tube?

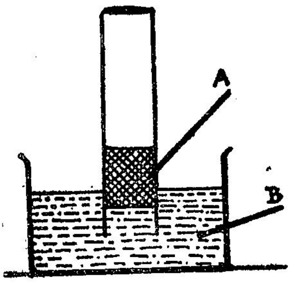
10. If a salt solution is given, how will you proceed to find the specific gravity?

11. In a *U* tube experiment the height of 12 cm. of water balances a height of 15 cm. of kerosene. Calculate the specific gravity of kerosene.



U - Tube with unequal cross section of limbs
Fig. 16

12. A liquid of specific gravity 0·75 balances a height of 9 cm. of water column. Find the height of the liquid column.

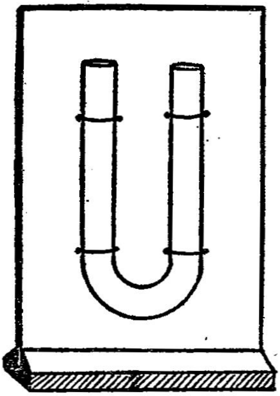


A - Kerosene B - Water
Fig. 17

13. Can you make use of a '*U*' tube whose limbs are of different cross section to find the specific gravity? Give your reasons for the answer.

14. A trough contains water. A glass tube of a small cross section is inserted into the trough and kerosene is poured into

the glass tube. Can we make use of this arrangement to calculate the specific gravity of kerosene? Give reasons for your answer.



Simple Aid - Individual Expt
Fig. 18

Do it Yourself

Take a plastic or polythene tube of 1 cm. diameter and length of 1 metre. Bend it in the shape of the letter *U* and fix it to a cardboard stand. Try to use it to find the specific gravity of oil in your house.

5. HARE'S APPARATUS

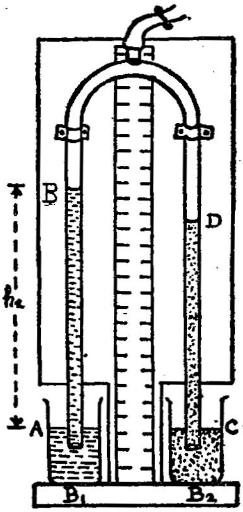
In the last lesson you read about the use of *U* tube for determining the specific gravity of liquids immiscible with water. If the liquid freely mixes with water, it will be difficult to use a *U* tube. Hence for liquids of the second type, we have a separate apparatus called the Hare's apparatus. This apparatus can be safely used to determine the specific gravity of liquids for both miscible and immiscible with water.

Hare's apparatus

Fig. 19 shows the construction of a Hare's apparatus. It is the upside down figure of letter *U*. It is fixed to a wooden support to enable it to stand erect on a table. A small exit tube is fused to the bent portion of the apparatus at the top. A small length of rubber tubing is also attached which carries a pinch cock for air tight closure. Small beakers are placed underneath the limbs of the apparatus to hold the liquid and water. A vertical scale is also fixed to the board to measure the liquid levels.

To determine the specific gravity of a liquid using the Hare's apparatus.

Place the Hare's apparatus on the table and take the given liquid in one of the beakers. Take water in the second beaker. See that the ends of the tubes are well immersed in the liquids. Slowly suck out air from the apparatus by releasing the pinch cock. Care should be exercised to see that the liquids are drawn only to 3/4 of the height of the apparatus, lest the liquids may mix with each other at the top or even enter your mouth. Close the pinch cock and wait for some time to see if there is any leakage in the apparatus. When the levels of the liquids are steady, read out the measurements on the scale against the liquid level and the water level in the limbs as well as in the beakers.



Hare's Apparatus
Fig. 19

(If the levels of the liquids slowly fall, it indicates a leakage and the pinch cock and the rubber tube should be made air tight).

The difference in levels of water in the beaker and the limb of the apparatus is the height of water column and the difference between the levels of the liquid in the beaker and the limb of the apparatus is the height of liquid column. After taking the first reading, gently release the pinch cock so that the levels of the liquids fall a little and take fresh readings. By repeating this take five or six readings and tabulate them.

Calculation

The liquids in both the limbs are in contact with the air inside the bent portion of the apparatus. The air exerts its pressure on the liquid and the water in the limbs. Since the pressure of air exerted on both the limbs is the same, the levels

of liquids remain steady. In turn, the liquids exert an upward pressure on the air and the thrust due to water is equal to the thrust due to the liquid.

Let us take the height of the water column above the water level in the beaker to be h_1 cm. and that of the liquid above the liquid level in the beaker to be h_2 cm. If the densities of water and the liquid are d_1 and d_2 respectively, we can calculate the pressure of the liquid and water.

The pressure due to water column is $h_1 d_1$ and pressure due to liquid column is $h_2 d_2$. The two pressures are equal as the liquid levels remain stationary. Hence

$$h_2 d_2 = h_1 d_1$$

$$\frac{d_2}{d_1} = \frac{h_1}{h_2}$$

The specific gravity of the liquid is given by the formula $\frac{d_2}{d_1}$ and therefore for the Hare's apparatus the specific gravity liquid can be calculated using the ratio $\frac{h_1}{h_2}$.

$$\text{Specific gravity of the given liquid.} = \frac{\text{Height of water column}}{\text{Height of liquid column.}}$$

Tabulation

Ex. No.	Water level in		Height of water column	Liquid level in		Height of liquid column	Sp. Gr.
	beaker C	limb D	$D-C=h_1$	beaker A	limb B	$B-A=h_2$	$=\frac{h_1}{h_2}$
1.							
2.							
3.							

Points to remember

1. The apparatus should be erect on the table.
2. The ends of the limbs should be well immersed in the liquids.
3. Air bubbles should be removed if any.
4. Pinch cock should be made air tight.
5. Liquids should not be sucked more than the 3/4 of the height of the apparatus.
6. Parallax error should be avoided.
7. The lower end of the tubes should not touch the bottom of the beaker containing the liquids.

Questions

1. Why should not the *U* tube be made use of for finding the specific gravity of all liquids?
2. In what way is the Hare's apparatus advantageous than that of *U* tube?
3. Draw a neat sketch of the Hare's apparatus.
4. Which do you prefer — a *U* tube or a Hare's apparatus to find the specific gravity of salt solution?
5. Describe an experiment to determine the specific gravity of a liquid using the Hare's apparatus.
6. What are the points to be borne in mind while using a Hare's apparatus?
7. Deduce the formula for Hare's apparatus to determine the specific gravity of a liquid.
8. Why should the lower end of the limbs of the Hare's apparatus be well immersed in the liquids?

9. What makes the liquids to rise in the limbs of the apparatus when you suck the air out of the apparatus ?

10. Calculate the height of water column if a liquid of specific gravity 1·2 is standing to a height of 25 cm. in a Hare's apparatus.

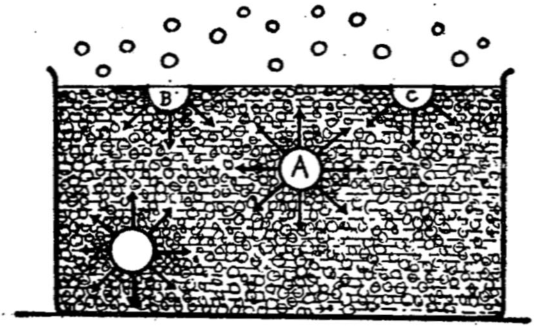
11. Calculate the height of liquid column that could be balanced by 30 cm. of water column. Assume the specific gravity of the liquid to be 0.8.

12. If 40 cm. of water column is balancing a height of 50 cm. of liquid column, calculate the specific gravity of the liquid.

6. SURFACE TENSION

All substances are made of molecules. Between the molecules, there is a force of attraction. Due to this force, the surface of a liquid exhibits a property known as surface tension.

Fig. 20 represents the microscopic view of the situation near the surface of a liquid. The closely arranged circles are molecules in the liquid on the surface or just below it. The circles shown here and there scattered indicate the few molecules in the vapour state.



Appearance of Water Molecules
Fig. 20

Consider a molecule at '*A*' inside the liquid It is surrounded on all sides by other molecules. Their forces of

attraction are equal in all directions. There is no resultant force acting on it. Hence the molecule at '*A*' remains in equilibrium.

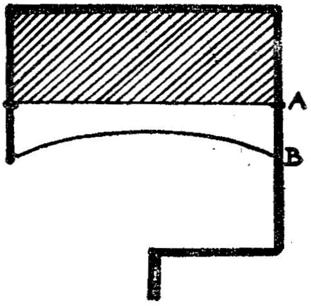
Consider another molecule at '*B*' or '*C*' on the surface of the liquid. There are many molecules beneath '*B*' or '*C*' and also horizontally on all sides. But there are fewer molecules on the surface above of the molecules at '*B*' or '*C*'. Even the fewer molecules are far and wide. Thus the forces acting downward on the molecule at '*B*' or '*C*' exceed those upwardly directed forces and hence there is a resultant force urging the molecule to move inward, away from the surface. All the other molecules at the surface are also subjected to a similar inward force. These forces are responsible for the phenomenon called '**surface tension**'.

The inward force is the same for all the molecules at the surface and hence there is a tendency of any liquid to minimise the area of the surface though other stronger forces may prevent this. A spherical shape will have the least surface area and hence for a given mass of liquid, spherical shape is the ideal to keep the surface area minimum. All liquids tend to form a spherical droplet. Thus the liquid surface seems to act like an elastic skin.

To show that a liquid surface acts like a stretched rubber membrane

Bend a long thick copper wire into a shape as shown in Fig. 21. Tie between the limbs a small thin wire such that it can slide easily over the length of the wire.

Initially let the thin wire be at *A*. Immerse the arrangement in a soap solution and remove it. What do you find? Thin soap film is formed between the wire frame and the thin wire. Then carefully draw the thin wire to the position *B* without breaking the soap film and leave the wire. Observe what happens. You will be surprised to see that the thin wire is drawn back to its original position *A* in a trice. It is just like the



The surface of a liquid acts as stretched membrane

Fig. 21

action of a rubber chord stretched by a weight and then released. Hence understand that the liquid surface acts like a stretched rubber membrane.

Measure of Surface Tension

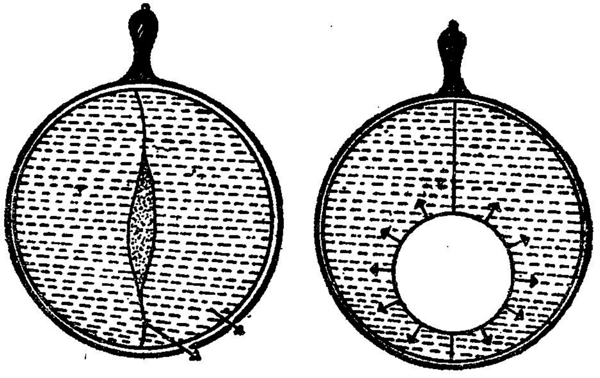
Surface tension cannot be represented by force units alone as the surface of the liquid acts like a membrane. It is usually represented by *dyne/cm* or *N/m*. Different liquids have different forces of surface tension.

Surface Tension and every day life.

Capillary action of liquids is possible due to the force of surface tension. Wetting and non-wetting of surfaces are made possible by this force of surface tension. We make use of this property for preparing the rain coats and tents for campers. Lead shots are manufactured using this property. Liquid lead is sprayed at the top of tall jars. When lead descends due to the gravitational forces, tiny droplets of lead are formed and they assume the spherical shape owing to the action of surface tension and fine leadshots are produced in this way.

Experiments with Soap Films

1. Bend a thick wire into the shape as shown in the figure.

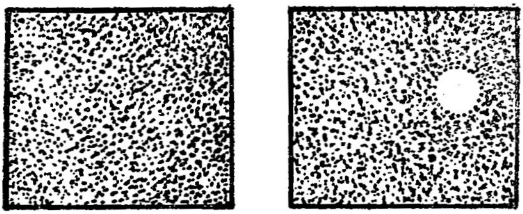


Soap film
Fig. 22

Tie a thread across the diameter of the circle thus formed. Immerse the arrangement in a soap solution and take it out. A

thin soap film will be formed between the frames. If you pierce the soap film in between the threads, they will be pulled apart by the action of forces of the soap film and the thread assumes a perfect circular shape.

2. Spray a thin layer of lycopodium powder onto a surface of water in a glass trough. Touch the surface with a stick or



Water surface sprinkled with lycopodium powder
Fig. 23

your finger previously dipped in soap solution. You will be surprised to find the powder pulled on all sides and perfect circles are formed in between.

3. Tie a piece of soap cake to the bottom of a toy duck and float it in water. You will see that the duck moves here and there due to the action of soap which reduces the surface tension of water.

Know Yourself

All liquids assume the spherical shape when in small quantities. Mercury also forms small pellets. If you go on adding more and more mercury, the size of the sphere grows bigger and bigger and at the same time the top portion becomes flat. Can you give the reason for this phenomena?

The density of mercury is high. Hence when the quantity of mercury increases in the drop, its

Mercury Pellet
Fig. 24

weight also increases. In order to balance the weight of the droplet of mercury it lowers the centre of gravity by

flattening the top surface. Here the surface tension and gravitational force are responsible for the phenomena.

Do it Yourself.

Take a trough of water. Float a blotting paper carrying a small pin or a blade. After some time the blotting paper sinks to the bottom while the pin or the blade floats on the surface. Can you give reasons for the action of the pin?

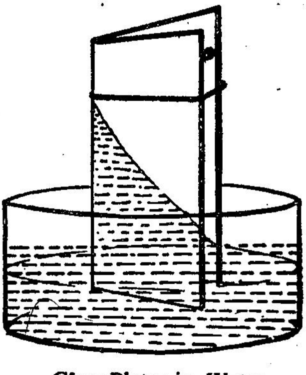
Questions

1. What are the factors responsible for surface tension?
2. Surface tension is due to the inter molecular force acting on the molecules. Explain.
3. Why should a drop of water assume a spherical shape?
4. Show that the surface of the liquid acts like a thin stretched membrane.
5. What is the unit of surface tension?
6. Name the agents that reduce the surface tension.
7. Water does not stick to lotus leaves. Why?
8. How are the camping tents made water proof?
9. How is fine lead shot manufactured?
10. Describe an experiment to show the force of surface tension of water.
11. How is surface tension of liquids useful in daily life?
12. Why are soaps and detergents made use of in laundrying?
13. Dew and mercury pellets assume spherical shape. Why?

14. Give reasons for the following :
    (a) Water wets the surface of a clean glass, but not a dusty glass.
    (b) A small piece of camphor is placed at the tail of a cardboard cut into the shape of the fish. It moves here and there in the water when the cardboard is placed in water.

7. CAPILLARITY

Have you seen self-inking pens? Just insert the nib of the pen into a bottle of ink and the pen is filled with ink in a second. How does the water rise up in the stalk of the plant? Let us do this experiment. Take two plane glass plates of any size and tie them together. Arrange to make a small gap at one end of the glass plates by inserting a pin in between the plates. Place this arrangement in a trough of water and you will see that the level of water assumes a curved path rising to the highest point where the glass plates are together and least in the portion where the plates are apart. Why?



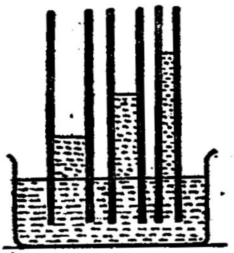
Glass Plates in Water
Fig. 25

Place a small piece of blotting paper on a patch of ink which is on the table and immediately the ink is absorbed by the blotting paper. We come across many phenomena like the one stated above and of course you will be eager to know why such things happen.

In the last lesson you have read about surface tension and this force is responsible for the liquids to rise up in narrow paths. The phenomenon of liquids rising against the force of gravity in a narrow tube is called capillarity. The rise of the liquids in capillary tubes depends on the diameter of the tube and the density of the liquids.

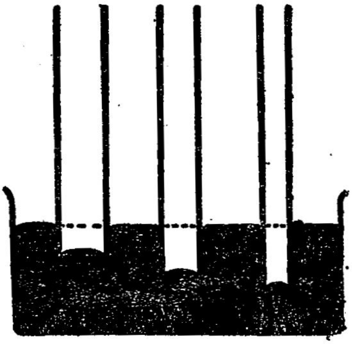
Capillarity-Demonstration

Fix several glass tubes of varying diameters in a trough of coloured water and observe what happens. Fig. 26 shows three such tubes and the levels of water in the tubes are different. The height to which the water level rises in the broad tube is the least and the height to which the liquid rises in the narrowest tube is the highest.



Capillary Tubes in Water
Fig. 26

Take out the tubes and this time keep them erect in a trough of mercury. Now you will see that the levels of mercury are depressed in varying depths. The broader the tube the lesser the depression of mercury. From the experiments conducted, we understand that the force due to capillarity increases with the decrease of inner diameter of the tube. Liquids with lesser densities rise up in the capillary tube and liquids of higher densities are depressed in the tubes.



Capillary Tubes in Mercury
Fig. 27

Advantages of Capillarity Forces

Water is sustained in the upper layers of the soil due to the capillarity action of the sand particles beneath. The same force is responsible for the rise in the tube or stalk of the plants. The same force is involved in the self-filling pen, blotting paper and bath towels.

The Wick of the Lamp

Cotton wicks are made use of in oil lamps. The oil from the reservoir climbs up the wick and is burnt. The wick acts as a capillary tube here and the force of capillarity makes

oil climb up. If the wick is pulled out a little and left, the oil will flow out as if it was a syphon tube.

In the same manner, if you pull out one of the long cloth immersed in a bucket of water, the water will automatically flow out. The threads in the cloth act as capillary tubes and provide the syphoning effect.

For Thought

A capillary tube of very fine inner diameter can give rise to water a height of 15 cm. If so, can we have an arrangement as shown in Fig. 28. to have an effortless pumping of water from a lower level to a higher level?

(Ans. We cannot have an arrangement like that as atmospheric pressure and gravitational forces are also involved. Surface tension alone cannot do this work.)

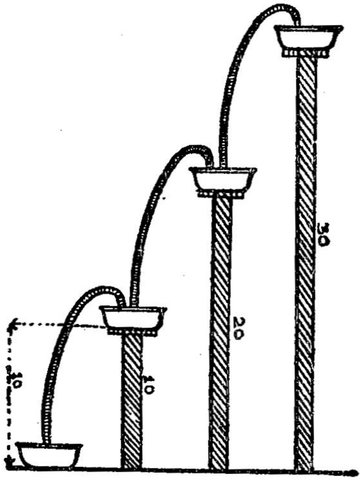


Fig. 28

Questions

1. What is meant by capillarity?
2. Can you tell what will happen if a capillary tube is inserted in water and then in mercury?
3. On what factors do the height reached by the level of the liquid depend upon in a capillary tube?
4. Describe an experiment to show that water rises to different levels in different tubes.
5. What is the use of capillary action in day-to-day life?
6. How does a wick function?
7. If you just pull out the wick from a lamp and allow it to hang down, what do you expect to happen?

8. VISCOSITY

In the lower standards you have read about friction. If two surfaces move one over the other, there arises a frictional force. The frictional forces always wear out the parts and also produce heat. In all the cases you have read about solid frictional forces. Is there a frictional force in the liquids also? Can there be friction in liquids and gases? What kind of friction will it be if such a thing happens? Let us learn all these things in this lesson.

When you swim in a river or push a boat, you will experience a slight resistance in the water. What does it show? It shows that there is friction in water. The same thing happens in all the liquids. This frictional force is due to the viscosity of the liquid. Highly viscous liquids exhibit high frictional force and less viscous liquids have less force.

Comparison of Viscous Liquids

Take two tall jars. Fill one with castor oil and the other with water. From the top of the jars allow a lead shot to fall freely in both the jars at the same time. Calculate the time taken by the lead shot to reach the bottom of the jar in both the liquids. You will find that the lead shot takes lesser time to reach the bottom in water than in castor oil. Hence we understand that a highly viscous liquid offers greater resistance to the movement and hence a lot of friction is offered by it.

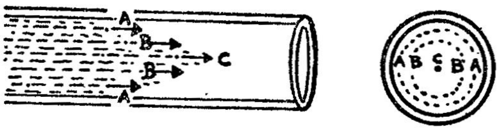
Advantages of Viscous Liquids

Wherever there is a moving part, it is subjected to frictional forces. To overcome friction, the parts are lubricated. Different kinds of oils are made use of for lubrication purposes. They range from highly viscous liquids to low viscous liquids. It is the viscosity of the liquid that decides the suitability of the said liquid to a particular part for lubrication.

Friction offered to flow of Water in a Tube

Let us consider the flow of water in a tube. Its molecules at the outer surface are touching the sides of the tube. The

layer *AA* is in contact with the sides of the tube and is subjected to the maximum friction. Hence the layer is at rest while



Flow of Liquid through a Tube
Fig. 29

the layer below it-*BB*-is not subjected to such a frictional force. The layer *BB* is moving with velocity as it is not subjected to so much of friction as in the layer *AA*. Hence when water flows in a tube, one can have different layers at different velocities. We also have different frictional forces at those layers. You will be reading more about it and also about viscosity in detail in your 11th and 12th standards. Just remember that scientist **Oswald** divised an apparatus to compare the viscosities of liquids and that apparatus goes by the name 'Oswald Viscometer'.

Questions

1. What is meant by viscosity ?
2. How will you compare the viscosities of two liquids ?
3. What are the advantages of viscosity ?
4. Explain the frictional forces produced in layers of liquids flowing through a tube.
5. Which is a highly viscous liquid—coconut oil or salt solution or castor oil ?
6. When you invert a beaker containing water, it quickly flows out. But honey in a beaker does not flow out so easily. Why ?

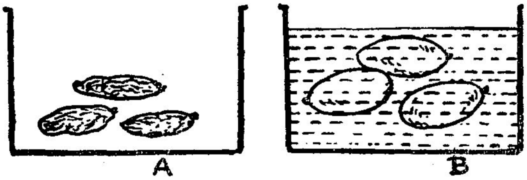
9. OSMOSIS

Have you tasted 'mavadu' pickles ? Fine varieties of small round shaped mangoes are plucked from trees and soaked in salt water. After a day or two, you will notice that the

Mango
A–Before putting into salt solution
B–After putting into salt solution
Fig. 30

mangoes are shrunk in size and a lot of wrinkles are formed on its body.

Take dried grapes and put them in a beaker of water. After some time, you will see that the grapes are swollen and become big in size.



Grapes
A–Before putting into water
B–After putting into water
Fig. 31

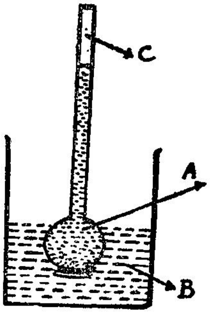
In all the cases stated above, you will find that water leaks out of the body in one case and in the other, water gets into the body. How does it happen ? Let us analyse.

Experiment

Fix a thistle funnel to a stand as shown in Fig. 32. Tie a goat's membrane or cellophane paper to it. Pour copper sulphate solution into the funnel and mark the level of

the solution in the stem of the funnel. This arrangement is made to stand in a beaker of water. Observe the funnel after some time. You will see that the level of the solution in the funnel has risen.

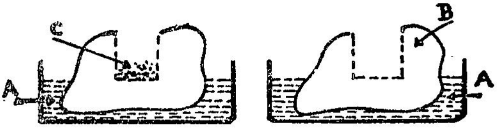
The density of the liquid in the funnel is greater than the density of water in the beaker. They are separated by a thin membrane. Water molecules on both sides move through the membrane from one side to the other. But the number of molecules that enter the funnel through the membrane is greater than the number of molecules of water that leave the funnel. Hence the water content of the funnel increases, resulting in the increase of the level.



A–Copper sulphate solution B–Water C–Thistle funnel
Fig. 32

If two liquids of different densities are separated by a thin membrane, the less denser liquid flows through the membrane into the more denser liquid. This phenomenon is called osmosis.

Do it Yourself



A–Water B–Potato C–Sugar
Fig. 33

Take a good sized potato and carve a small cavity in it. Place some sugar crystals in the cavity and keep the potato in shallow trough of water. After some time you will see that water from the trough has crept into the potato to reach the sugar crystals. The same experiment can be repeated with a carrot.

Effects of Osmosis

Plants : Root hairs absorb the nutrient water from the soil by the process of osmosis. The liquid in the cells of the root hairs

have greater density than the soil water. The cell wall of the root hair acts as the membrance and osmosis takes place. In the same way water flows from one part of the plant to the other.

Animals : Digested food materials are assimilated into the blood due to the action of osmosis taking place in the small intestine.

Questions

1. What is meant by osmosis ?
2. Explain with a neat sketch the experiment on osmosis.
3. How is osmosis useful in life ?
4. Give reasons for the following : (*a*) Fruits placed in salt solution shrink while dried fruits placed in water swell. (*b*) Place some salt crystal inside the cavity of a carrot and place it in water. In a short time water finds its way into the cavity to dissolve the salt crystals.

III. Heat

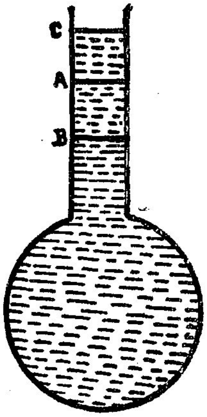
10. EXPANSION OF LIQUIDS

There are three states of matter i.e. solids, liquids and gases. You have already studied in the previous year about the expansion of solids. In this lesson you will learn more about the expansion of liquids and gases.

Liquids have no definite shape or size. They always attain the shape of the vessel in which they are contained. But liquids have definite volume. When liquids are heated, they expand in volume but not in length or area.

Look at Fig. 34. The glass vessel contains water. Let us see what happens when we heat it. Mark the level of water in the vessel. When heat is applied to the vessel, let us observe

the events for a fraction of a second. In this period, the vessel alone gets heated up and the heat applied had not reached the liquid inside. The container alone expanding in volume results in the lowering of the level of the water in the container. After this the heat passes onto the liquid also. The water in the vessel also expands resulting in the increase in the level of water. When maximum expansion has taken place, the level of water remains steady at a level higher than the previous level. The level of water before the beginning of the experiment is indicated by '*A*'. When heat is applied and the vessel alone expands, the level of water drops to '*B*'. Afterwards when the heat expands to water also, the level reaches to '*C*'. What do we understand from this? When a liquid in a container is heated, what we see is only the apparent expansion of the liquid and not its real expansion. The real expansion of the liquid includes the expansion of the container also. Hence we conclude that the liquids have two types of volume expansion ; an apparent expansion and an actual or real expansion.



A–Water level before heating B–Water level when flask alone expands C–When Water also expands.
Fig. 34

Real expansion of a liquid = Volume expansion of the container + apparent expansion of the liquid.

$$BC = BA + AC.$$

Definitions

Coefficient of apparent expansion of liquids

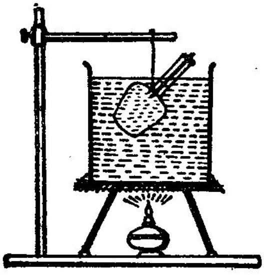
The increase in volume of a cubic centimetre of a liquid in a vessel for a raise of 1°C is called the coefficient of apparent expansion of the liquid.

Coefficient of real expansion of liquids

It is the ratio of the true increase in volume experienced by the liquid to its volume at 0°C when its temperature is raised by 1°C.

To find the Apparent Expansion of Coconut Oil

Find the mass of a clean dry 25 ml. specific gravity bottle. Fill it with the given liquid taking care to avoid air bubbles. Replace the stopper and wipe out the overflowing liquid. Then weigh it again. The difference between the two gives the mass of the liquid taken.



Apparent Expansion of Liquid
Fig. 35

Place a beaker half filled with water over the wire gauze and place it on a tripod stand. Carefully suspend the specific gravity bottle so that it is fully immersed in water up to its neck. Stir the water and note its temperature. Use a spirit lamp to heat the beaker. As the water gets heated up, the liquid in the specific gravity bottle also gets heated up. The heat of the water makes the liquid to expand. Coconut oil from the bottle slowly oozes out. Quickly wipe out the oil from the specific gravity bottle with a blotting paper. Go on doing this until there is no more oozing out from the bottle. This will happen when the water begins to boil. The maximum expansion of the liquid will be obtained at the boiling point of the water. Take out the specific gravity bottle and allow it to cool. After it comes to the room temperature, weigh it again.

In this experiment the same liquid suffers change of temperature and it is assumed that the mass of the liquid is proportional to its volume. Hence in the place of increase in volume, we are taking the change in mass of the liquid.

Calculation

Mass of the sp. gr. bottle with stopper (empty)	$= w_1$ gms.
Mass of the sp. gr. bottle with the given oil	$= w_2$ gms.
Mass of the sp. gr. bottle with remaining liquid	$= w_3$ gms.
Initial temperature of the water bath	$= t_1$°C
Final temperature of the water bath	$= t_2$°C
Mass of the liquid remaining in the sp. gr. bottle	$= w_3 - w_1$ gms.
Mass of the liquid that has been expelled by heat	$= w_2 - w_3$ gms.

If $w_3 - w_1$ gm of oil is heated from t_1°C to t_2°C, it expands and fills the whole bottle when the mass of the liquid expelled will be $w_2 - w_3$ gms.

Therefore if 1 gm. of oil is raised through 1°C, the expansion, it will suffer will be

$$= \frac{w_2 - w_3}{(w_3 - w_1)(t_2 - t_1)}.$$

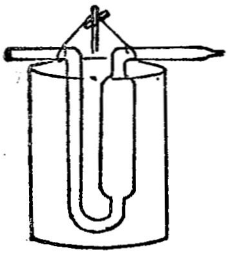
This is called the apparent expansion of the liquid. By solving the equation, the apparent expansion of coconut oil can be determined.

To determine the Real Expansion of the Liquid

First determine the apparent expansion of the liquid. Then add the cubical expansion of the vessel in which it is contained. We get the real or actual expansion of the liquid.

Know Yourself

In the place of a specific gravity bottle a device as shown in the figure can also be used to determine the apparent expansion of the liquid. This device is called the Pyknometer. Learn how this can be used.



Pyknometer
Fig. 36

Questions

1. How do you know that liquids expand in volume only?
2. What is meant by coefficient of apparent expansion of liquids?
3. What is meant by coefficient of real expansion of liquids?
4. What do you expect to happen if the bulb of the mercury thermometer is carefully immersed in warm water? Explain.
5. What is the relationship between the apparent expansion and the real expansion?

6. How will you determine the coefficient of apparent expansion of a liquid ?

7. What other devices can be made use of to determine the apparent expansion of the liquid ?

8. How will you find out the real expansion of a liquid ?

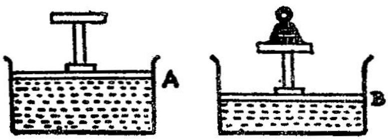
9. Mass of an empty sp. gr. bottle is 24·53 gm. Its mass is 51·30 gm when a liquid is filled in it. When its temperature is raised from 25°C to 100°C, the mass of the sp. gr. bottle is found to be 49·53 gm. Calculate the apparent expansion of the liquid.

Do it Yourself

Try to find the apparent expansion of turpentine oil in your school laboratory.

11. BOYLE'S LAW

Observe the working of a cycle pump. When you close the lower hole and push the piston, your hand experiences the pressure of air. At the same time, you will see that the space under the piston becoming less and less.



Pressure—Volume Relation
Fig. 37

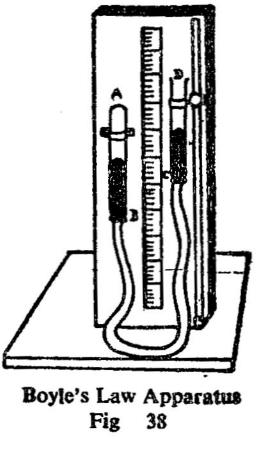
Arrange a divice as shown in Fig. 37. Mark the position of the piston before the experiment as *A*. Place a 5 kg. weight on the head of the piston. The piston moves down due to the weight. Mark the new position as *B*. Originally the air in the vessel occupies a space upto the mark *A*. After theweight is added, the air occupies a lesser space upto the mark *B*.

Experiments were conducted in the above manner and **Robert Boyle** discovered a relationship between pressure and volume of a gas. He ennunciated a law and it is called **the Boyle's law.**

It is stated thus : *Temperature remaining constant, the volume of a given mass of gas varies inversely as its pressure.* If pressure is measured as P and volume as V, then under constant temperature $P = \frac{1}{V}$ or $P \times V$ = constant. Temperature remaining constant when the volume of a given mass of gas is measured at different pressures, then from Boyle's law, it is clear that $P_1 \times V_1 = P_2 \times V_2 = P_3 \times V_3 = P_4 \times V_4$.

To verify Boyle's Law

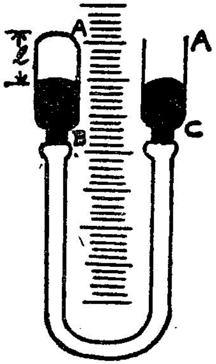
Boyle's law apparatus comes in handy to verify the law. The apparatus is as shown in Fig 38. Two glass tubes are made use of in this apparatus. One of the glass tubes is closed at one end while the other is open at both ends. They are connected by a long rubber tube. The closed tube is AB fixed permanantly at a place in the wooden stand, while the open end tube CD is fixed in such a way that it can be moved up or down and fixed in position wherever needed by a special arrangement. A vertical scale is also fixed along the length of the stand. The glass tubes are partially filled with mercury while the entire rubber tube is full of mercury. Some air is arrested in the closed tube A above the mercury level.



Boyle's Law Apparatus
Fig 38

By measuring the volume and the pressure of this enclosed air in the apparatus, Boyle's law is verified. Here we assume that since the tube is very narrow, the volume of the air enclosed is proportional to the length of the air column above

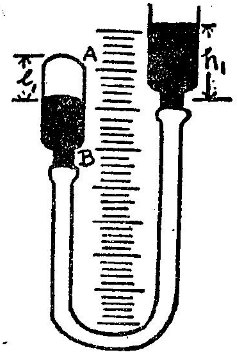
the mercury level. The length of air in the closed tube above the mercury level is directly taken as the volume of the air.



The Pressure of the Enclosed Air is equal to the Atmospheric Pressure
Fig. 39

Note down the reading of the tip of the closed tube on the scale. Lower the open end such that the levels of mercury in both the tubes are in the same level. At that time the pressure acting on the mercury level in the open end is equal to the pressure exerted by the atmosphere. When the two levels of mercury are the same, the pressure of the enclosed air is equal to the atmospheric pressure. Find the length of the enclosed air by noting down the mercury level in the closed tube.

Then raise the open tube such that the level of mercury in the closed tube increases. Correspondingly the level of mercury in the open tube falls. Note that the spaceabove the mercury level in the closed tube is reduced. Note the levels of mercury in both the closed and open tubes. Find the length of the enclosed air.

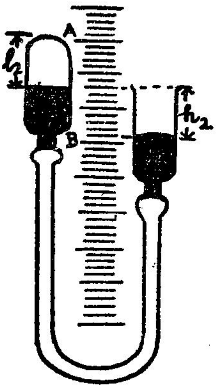


The Pressure of the Enclosed Air is greater than the Atmospheric Pressure
Fig. 40

Next lower the open end such that the level of mercury in the closed tube falls while the level in the open end rises. This time the space above the mercury level in the closed tube increases. Note down the levels of mercury in both the tubes. Also note down the length of the enclosed air.

In the first experiment the pressure of the enclosed air is equal to the atmospheric pressure. Multiply this pressure by the volume of the enclosed air.

In the second experiment the pressure of the enclosed air is greater than the atmospheric pressure by a value equal to the difference between the mercury levels in both the tubes. Find the product of the pressure and the volume of the enclosed air in this case also.



The Pressure of the Enclosed Air is less than the Atmospheric Pressure
Fig.41

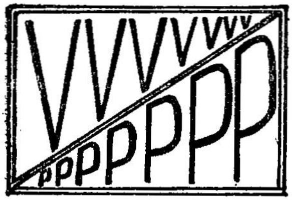
In the third experiment, the pressure of the enclosed air is less than the atmospheric pressure by a value equal to the difference between the two mercury levels. Find the product of the pressure of the enclosed air and the volume of the air. It will be found that the product of the volume and pressure of the enclosed air in all the experiments remains the same, which proves Boyle's law.

Tabulation.

No.	Atmospheric Pressure A	Readings in the closed Tube		Volume of enclosed air $T-Q=V$	Mercury level in open tube R	Difference in mercury levels $h=R-Q$	Pressure of enclosed air $P=A\pm h$	$P \times V$
		Tip T	Mercury level Q					
1.								
2.								
3.								

For Thought

1. The following diagram can very easily be used to remember Boyle's law. Can you explain how?



Pressure inversely proportional to Volume
Fig. 42

2. All gases generally obey Boyle's law. But there are certain situations where they don't. You will know more about this under the lesson vapour pressure.

Questions

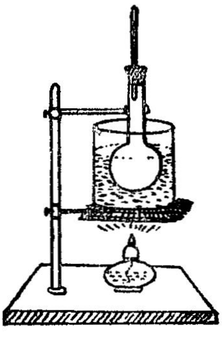
1. What will happen if the pressure of the volume of the gas is reduced slowly without allowing the change of temperature?
2. Name the scientist who investigated the relationship of the pressure and volume of a gas.
3. State Boyle's law.
4. Why should there be a condition that 'temperature should remain constant' while verifying Boyle's law?
5. Draw a neat sketch of the Boyle's law apparatus.
6. Describe the experiment to verify Boyle's law.
7. How does the pressure of the enclosed air is altered in the Boyle's law apparatus?
8. It is not advisable to lower the open end tube beyond a limit. Why?

12. EXPANSION OF GASES

You have read in the lower classes that matter exists in three states. They expand when heated. Solids and liquids expand in volume while gases expand in volume and pressure. When pressure remains constant, gases expand in volume and when volume remains constant, the pressure increases.

Volume Expansion of Gases

Take a 250 ml. flask and cork it with one holed rubber stopper. Fix a capillary tube through the hole in the stopper. By slightly warming the flask, draw carefully a small pellet of mercury in the capillary tube. Place the flask in a trough of water fully immersed upto its neck. Note the level of mercury pellet in the tube. It indicates the volume of air in the flask. Note the temperature of cold water. Then heat the trough of water. As the temperature of water increases, the air in the flask expands. It pushes the mercury pellet up. The position of the mercury pellet indicates the volume of the air in the flask. The air is subjected to the atmospheric pressure and the pressure due to the mercury pellet. Here, during the experiment, there is no change of pressure. So the experiment shows that under constant pressure, the gas undergoes volume expansion.



Volume Expansion of a Gas
Fig. 43

Pressure Expansion of Gases.

When the volume of a gas remains constant, the pressure undergoes a change due to the change of temperature. Take a 250 ml. flask and cork it tight with a rubber stopper which has no hole. Now a certain volume of air is enclosed in the flask and its volume will remain unchanged throughout the experiment. Now heat the flask and allow the temperature to rise. Because of the heat, the air tries to expand. But there is no scope for it as it is enclosed in a tight flask. At a particular temperature, you will see that the flask explodes with a noise. The explosion of the flask is caused by the pressure of air inside. Hence we understand that the pressure will increase if the volume of a given mass of gas remains constant.

The same result will be achieved if, instead of air, some gas is used in the 250 ml. flask.

The expansion of gas is greater than the expansion of a solid or liquid for a given rise of temperature. Hence the volume or the pressure of the gas at $O°C$ is always taken as the initial reading for all calculations.

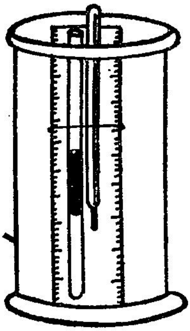
Definitions

Volume coefficient of gas : *Pressure remaining constant, the ratio of the increase in volume of a gas for 1°C rise to the volume of the same gas at O°C is called the volume coefficient of the gas.*

Pressure coefficient of a gas : *Volume remaining constant, the ratio of the increase in pressure of a given mass of gas for rise of 1°C to the pressure of the same gas at O°C is called the pressure coefficient of the gas.*

To determine the Volume Coefficient of a Gas

Take a capillary tube of 1 metre length and draw a mercury pellet of 10 cm. length into it. Move the mercury pellet to the middle of the tube and fuse the end of the capillary tube so that a small column of air is enclosed between the closed end and the mercury pellet. Keep the tube erect with its open end facing upwards into a tall jar of water. Fix a thermometer along with the tube to measure the temperature of the water. A metre scale is also fixed along with the tube to measure the length of the air enclosed at the closed end. Since the capillary tube is of uniform bore, the length of the air column is itself taken to correspond to the volume of the air.



Volume coefficient of a Gas
Fig. 44

Allow steam to pass into the water in the jar and make the water boil. When the water in the jar boils, note down the temperature. The heat of the water expands the air in the closed end of the tube which, in turn, pushes the mercury pellet up. Measure the length of the air column when the water is boiling.

Let us assume the volume coefficient of air as 'x'

At O°C its length is = 1 cm.

At 1°C the length = $1 + x$ cm.

At 2°C its length will become $1 + 2x$..... and so on

At 10°C its length will be $1 + 10x$ and at t°C its length will be $(1 + tx)$

Its length at t°C = $1 + tx$

If its length at O°C is l_0, then

its length at t°C = $l_0 (1 + tx)$

If its length at t_1° C is l_1, then

$$l_1 = l_0 (1 + t_1 x) \ldots\ldots (1)$$

If its length at t_2°C is l_2, then $l_2 = l_0 (1 + t_2 x) \ldots\ldots (2)$.

It is very difficult to measure the length of the air at O°C and in order to eliminate l_0 in the equation, we divide eqn. 1 by eqn. 2. Therefore,

$$\frac{l_1}{l_2} = \frac{l_0 (1 + t_1 x)}{l_0 (1 + t_2 x)}$$

$$\text{(i.e)} \quad \frac{l_1}{l_2} = \frac{(1 + t_1 x)}{(1 + t_2 x)} \ldots\ldots (3)$$

Here the value of all the factors except 'x' can be measured and the value of x can be calculated.

Cross multiplying the equation (3), we get,

$$l_1 (1 + t_2 x) = l_2 (1 + t_1 x)$$

$$l_1 + l_1 t_2 x = l_2 + l_2 t_1 x$$

$$l_1 t_2 x - l_2 t_1 x = l_2 - l_1$$

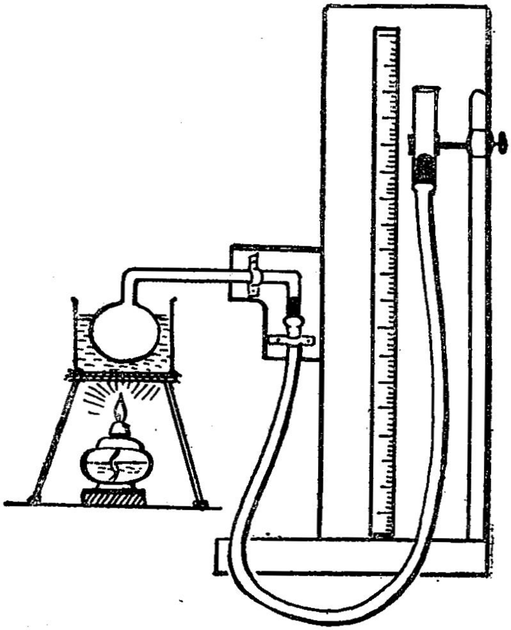
$$x (l_1 t_2 - l_2 t_1) = (l_2 - l_1)$$

$$x = \frac{l_2 - l_1}{l_1 t_2 - l_2 t_1}.$$

Thus the volume coefficient of the gas can be calculated.

To determine the Pressure Coefficient of a Gas

Jolly's bulb comes in handy in the determination of the pressure coefficient of a gas. The apparatus is nothing but a modification of Boyle's law apparatus. Instead of the closed



Jolly's Bulb Apparatus
Fig. 45

end tube in the Boyle's law apparatus, a small bulb carrying a narrow tube bent twice at right angles is made use of. A part of this tube, open end tube and the entire length of the rubber tube, is filled with mercury. Some air is enclosed in the bulb above the mercury level. In order to maintain the volume of the air to be constant, a mark is made near the mercury level in the tube attached to the bulb. During the experiment, the open end tube is either raised or lowered to bring the mercury level always to the mark to make the volume constant.

The bulb of the Jolly's apparatus is immersed in a beaker of water placed over a wire gauze on a tripod stand. The water is

stirred well and the initial temperature of the water is noted. The water in the beaker is then heated. When the water boils, note down the temperature. Raise the open end tube so that the mercury level in the bulb tube stands exactly at the mark already made. Note the reading of the mercury in the open tube. The difference between the levels of mercury gives the increase of pressure of the air in the bulb.

Calculation

Let us assume the pressure coefficient of the gas to be 'y'.

At $0°$C the pressure of the air is say 1 cm.

At 1°C the pressure will be $1 + y$ and

At $5°$C, it will be $1 + 5y$

At $20°$C, it is $1 + 20y$

At $t°$C its pressure will be $1 + ty$.

If at 0°C its pressure is assumed to be P_0, then

its pressure at $t°_0$ is $P_0 (1 + ty)$.

If at t_1°C its pressure is P_1, then

$P_1 = P_0 (1 + t_1 y)$....(1)

At t_2°C the pressure is $P_2 = P_0 (1 + t_2 y)$....(2.)

The pressure of air at 0°C is difficult to find and so in order to eliminate P_0, we divide equation 1 by equation 2. so

$$\frac{P_1}{P_2} = \frac{P_0 (1 + t_1 y)}{P_0 (1 + t_2 y)}$$

$$\text{or } \frac{P_1}{P_2} = \frac{(1 + t_1 y)}{(1 + t_2 y)}$$

In this equation all the quantities except 'y' can be measured experimentally. Hence 'y' can be calculated.

Cross multiplying, we get

$$P_1 (1 + t_2 y) = P_2 (1 + t_1 y)$$

$$\text{or } \quad P_1 + P_1 t_2 y = P_2 + P_2 t_1 y$$

$\therefore P_1 t_2 y - P_2 t_1 y = P_2 - P_1$

$\therefore y(P_1 t_2 - P_2 t_1) = P_2 - P_1$

or $$y = \frac{P_2 - P_1}{P_1 t_2 - P_2 t_1}$$

This experiment can be done at ranges of 10°C differences from the initial temperature when pressures P_1, P_2, P_3, . . . etc. can be recorded and tabulated as follows :

Tabulation

No.	Range of temperature	Level of mercury in the bulb tube (Constant volume)	Level of mercury in the open tube	Difference of level of mercury	Atmospheric pressure	Pressure coefficient of enclosed air
1						
2						
3						
4						
5						

Questions

1. What are the two types of expansion of gases ?
2. How will the gas expand under constant pressure ?
3. How will the gas expand under constant volume ?
4. Describe an experiment to show that gas suffers volume expansion under constant pressure ?
5. Why should a mercury pellet be introduced in the tube for conducting the volume expansion of a gas ?
6. Describe an experiment to show that gases suffer expansion of pressure under constant volume.

7. A tightly corked flask explodes when heated. Why?
8. Why should we take $0°C$ as the initial measurement when defining the volume or the pressure coefficient of a gas?
9. Define volume coefficient of a gas.
10. Define pressure coefficient of a gas.
11. Describe an experiment to find the volume coefficient of a gas.
12. Draw a neat sketch of the Jolly's bulb apparatus.
13. How will you determine the pressure coefficient of a gas using the Jolly's bulb apparatus?
14. Write down the formula for the volume coefficient of a gas.
15. Write down the formula for the pressure coefficient of a gas.

13. SPECIFIC HEAT

Have you not read about temperature in your lower classes? In this lesson you will read about specific heat and thermal capacity of a substance.

Take 50 gm. of water in a beaker. Note down its temperature. Suppose you want to raise the temperature by $1°C$, you must necessarily give sufficient heat to the beaker. If you want to raise the temperature by $2°C$, then you will need two times the quantity of heat. For $5°C$ rise, you need five times the heat.

Take now 100 gm. of water in the same beaker. If you want to raise the temperature of this water through $1°C$, then you will need twice the quantity of heat required to raise the temperature of 50 gm. of water. An increase in the weight of the liquid to be heated results in the increase of heat to be given.

If you repeat the above experiment with other substances in the place of water, you will realise that same quantity of heat is not sufficient to raise the temperature of each of the substances through 1°*C.*

What do you understand from this? The thermal capacity of the substances depend on the mass, range of temperature, and specific heat of the substances.

Difference between Temperature and Thermal Capacity

Take for example a kettle at 100°*C.* Let us assume that a cup of water is drawn from the kettle. Comparing the volume of water in the kettle, the volume of water in the cup is very small. The temperature of water in both the kettle and the cup is the same. But the heat content of the kettle will be more than the heat content of the cup. How can we explain this? Consider a vessel of the type shown in Fig. 46. The volume of one of the limbs of the vessel is larger than the other. If you pour water into one of the limbs; the water finds its level. Though the levels of water in both the limbs are the same, the volume of water contained in each limb will definitely vary. If you compare the level of water to the temperature of a body, the volume of water can be compared to the heat contents of the body. Temperature is denoted by degrees and the heat content of the body is denoted by the unit 'calorie'.

Illustration to explain Temperature and heat quantity
Fig. 46

Different Substances have different Thermal Capacities

When you apply heat to the substances, they register a rise in temperature. That is, they take the heat and bring about a change in their temperature. The substances have capacity to accept heat energy. But this capacity differs from substance to substance. The quantity of heat required to raise the temperature of a body by 1°*C* is known as the thermal capacity of the body and is expressed by the unit calorie.

Take identical glass beakers and place in them different substances which are at the same temperature. For example, take some quantity of water, mercury and copper. Light a burner which gives equal amount of heat in equal intervals of time and heat the beakers for 15 mts. Use a sensitive thermometer to register the rise in temperature of each of the substances. You will be surprised to find that though equal quantity of heat is given for equal times the rise in temperature is not the same. The water registers a small rise while mercury registers a large rise in temperature. From this we conclude that the thermal capacity of substances differ. Because of this difference in substances, several phenomena like sea breeze and land breeze occur.

Specific Heat

The ratio between the thermal capacity of the substance and the thermal capacity of the same mass of water as that of the substance is called the specific heat of the substance. Specific heat of water is high while that of mercury is low. Specific heat of water is 1.

To find the Thermal Capacity of a Substance

How much heat is required to raise the temperature of a substance through $1°C$? It depends on the mass, range of temperature, and the specific heat of the substance. Hence to calculate the heat required by a body, we multiply mass, specific heat and the range of temperature. The same quantity of heat is given out if the substance is cooled through $1°C$. Hence if Q is the quantity of heat required and m its mass, s its specific heat and t the range of temperature, then

$$\boxed{Q = m \times s \times t \text{ calorie.}}$$

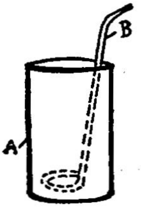
Problems

1. What is the quantity of heat required to raise the temperature of water of mass 200 gm. from $30°C$ to $50°C$? (Assume the sp. ht. of water as 1.)

$Q = m \times s \times t$ $m = 200$ gm. $s = 1$, $t = 50 - 30 = 20$.
Therefore $Q = 200 \times 1 \times 20 = 4000$ calories.

Calorimeter

It is a cylindrical metallic vessel, usually made of copper. A long copper wire or of the same metal with which the calorimeter is made is used as a stirrer. Sometimes the calorimeter is also made of aluminium. This vessel is made use of for heat exchange process between the substance at high temperature and a substance at a lower temperature. The calorimeter is kept in a wooden box to minimise heat loss or heat gain, and surrounded by non-conducting materials.



A - Calorimeter
B - Stirrer
Fig. 47

Water Equivalent of a Calorimeter

The mass in grammes of water having the same thermal capacity as that of the calorimeter is called the water equivalent of the calorimeter. For example if x is the thermal capacity of a calorimeter, then the water equivalent of the calorimeter is x gms. Thermal capacity is expressed in calories while the water equivalent is expressed in gramme.

Example: What is the water equivalent of a calorimeter of mass 50 gms? The sp. ht. of the material of the calorimeter is 0·1.

Water equivalent of the calorimeter is $50 \times 0{\cdot}1 = 5$ gms.

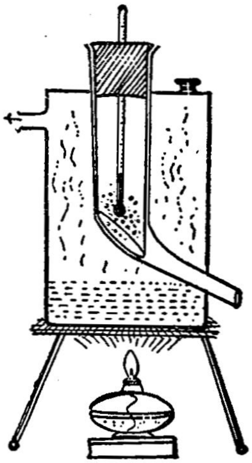
Method of Mixtures.

The specific heat of a solid can be calculated using the process called the 'method of mixtures'. In this process, the solid, whose specific heat has to be determined is heated to a high temperature and then allowed to mix with a substance of known specific heat at a low temperature. Heat is exchanged between the substances and we can calculate the heat lost by a hot substance and the heat gained by the cooler substance. By equating the heat lost and heat gained, the specific heat can be calculated.

The rule of the method of mixtures is that the heat lost by the hot body is always equal to the heat gained by the cooler body.

Steam Heater

The given solid is heated in a steam heater. It is a simple device where the solid is kept in position for a period until it is fully surrounded by the steam given out by the boiling water in the boiler. When the central cylinder is rotated, it releases the solids which glide through the slant bent tube and falls into the calorimeter kept underneath. A thermometer is well placed among the solid to register the temperature.



Steam Heater
Fig. 48

To find the Specific Heat of a Solid

Find the mass of an empty calorimeter along with the stirrer. Fill it up with water to a height of 1/3 of its volume and weigh again. The difference between the two mass gives the mass of the water taken. Place the calorimeter with water into the wooden box. Stir well and note the temperature.

The given solid is heated in a steam heater and when the temperature reaches 100°*C*, the solids are allowed to fall into the water in the calorimeter. The water is stirred vigorously and the maximum rise of temperature is noted carefully with a very sensitive thermometer. After the calorimeter attains the room temperature, it is weighed again with its contents.

Calculation

Mass of empty calorimeter with stirrer	$= a$ gms
Mass of calorimeter + 1/3 water	$= b$ gms
Mass of water taken	$= b - a$ gms
Initial temperature of calorimeter+water	$= t_1$°*C*
Temperature of the solid	$= t_2$°*C*
Maximum temperature reached by the mixture	$= t_3$°*C*
Mass of calorimeter + water + solid	$= c$ gms
Mass of solid taken	$= c - b$ gms

Specific heat of solid taken $= x$
Specific heat of calorimeter $= s$
Specific heat of water $= 1$

Heat gained: Here heat is gained not only by the water but also by the calorimeter which contains the water.

So, heat gained by the calorimeter $= a \times s \times (t_3 - t_1)$

Heat gained by the water $= (b - a) \times 1 \times (t_3 - t_1)$

Total heat gained by both the calorimeter and water
$$= as\,(t_3 - t_1) + (b - a)\,(t_3 - t_1)$$

Heat loss: In this experiment heat is lost by the solids whose specific heat is to be determined. Hence,

Heat lost $= (c - b)\,x\,(t_2 - t_3)$

According to the rule of the method of mixtures
heat lost = heat gained.

$$(c - b)\,x\,(t_2 - t_3) = as\,(t_3 - t_1) + (b - a)\,(t_3 - t_1)$$
$$\text{or } x = \frac{as\,(t_3 - t_1) + (b - a)\,(t_3 - t_1)}{(c - b)\,(t_2 - t_3)}$$

Thus the specific heat of a substance is calculated.

To find the Specific Heat of a Liquid by the Method of Mixtures

The very same experiment as detailed above is carried out. But here a solid of known specific heat is taken and the liquid whose specific heat is to be found is taken in the calorimeter instead of water.

Simple Heater
Fig. 49

If a steam heater is not available, the solids can be heated in a test tube as shown in Fig. 49. The test tube containing the solids is placed in the beaker of water. A thermometer is introduced in the test tube and some cotton is plugged to the mouth of the test tube to prevent the water droplets getting into the test tube.

Points to remember

1. Weighings should be accurate.
2. Temperature readings should also be accurate.

3. Use a highly polished calorimeter and stirrer to reduce loss of heat by radiation.

4. To reduce heat loss by conduction and convection, the calorimeter should be placed in a wooden box surrounded by non-conducting materials.

5. Transfer the hot contents into the calorimeter without any lapse of time.

6. When the solid is dropped into the calorimeter, see that the water is not splashed.

7. Always stir vigourously before taking the temperature reading.

8. Only $\frac{2}{3}$ of the calorimeter should be filled with water.

Advantage of Water having high Specific Heat

Water has the highest specific heat being taken as 1. Because of this quality, water is comfortably made use of for fomentation of body aches to relieve pain. Since water has high specific heat, it takes a long time to get heated up. Hence sea is cooler than the earth in hot days because of which sea breeze sets in the noon to cool the earth. Alternately land breeze sets in at nights to cool the sea which takes a longer time to cool than the earth. Just imagine that water has the least specific heat. In hot summer days, one may not get into a water pool since it will be at a high temperature! Water will never be used for ordinary purposes then.

Questions

1. How will you show that thermal capacity depends on mass, temperature range and sp. ht. of the substances?
2. What is the difference between heat capacity and temperature of a substance?
3. Show that different substances have different thermal capacities.
4. What is meant by thermal capacity?

5. Define specific heat.

6. Write down the formula for calculating thermal capacity.

7. A calorimeter contains 30 gms. of water at 15°C. Warm water of 30 gms. at 50°C is added to it and the resultant temperature is 30°C. Calculate the water equivalent of the calorimeter.

8. Define the water equivalent of a calorimeter.

9. Draw a neat sketch of a calorimeter.

10. What is meant by 'the method of mixtures'?

11. State the law of the method of mixtures.

12. Draw a neat sketch of the steam heater.

13. How will you proceed to determine the specific heat of lead shot?

14. How will you determine the specific heat of a liquid?

15. What are the important points to remember in a specific heat experiment?

16. What are the advantages of water having the highest specific heat?

17. A lead shot of 250 gms. mass at 98·5°C is dropped into a calorimeter of mass 46 gms. The calorimeter contains water of mass 85·4 gms. at 16°C. The resultant temperature is 23·5°C. Find the sp. ht. of lead shot. (Assume sp. ht. of calorimeter as 0·1)

A copper calorimeter of mass 32 gms. contains liquid of mass 175 gms. at 26°C. A lead shot of 300 gms. at 100°C dropped into the calorimeter raises the temperature to 32°C. Find the sp. ht. of the liquid if the sp. ht of lead shot is 0·03 and that of the calorimeter is 0·1.

14. LATENT HEAT

You have read in the lower classes that bodies undergo change of state when heat is applied to them. Solids melt to become liquids and liquids boil to become gases when heated. When heat is taken away from the bodies, gases tend to become liquids and liquids become solids. Heat makes the bodies to melt, to evaporate, and boil. Loss of heat makes the bodies condense and freeze.

When heat is applied to a body, there is another change in the body - a change in the temperature. Gain of heat raises the temperature of the body and loss of heat diminishes the temperature. Moreover, change of state occurs at a particular temperature.

Hence we understand that heat given to a body effects two things (1) the change of temperature and (2) the change of state.

How is the heat spent when the body is undergoing change of state ? The heat supplied at that stage is either used for effecting the change of state or raising the temperature of the body. Let us investigate the situation when wax is being melted. Until all the wax is melted, you will notice that the temperature remains constant. Otherwise, when change of state occurs, there is no rise in temperature until the process of change of state is complete. Look at the boiling water. The thermometer shows the temperture of boiling water and it remains the same until the entire water is converted into steam.

What is happening to the heat supplied to the wax or water at the change of state.level ? The heat supplied is used for the change of state of the substance. That is, heat supplied to wax at the melting point is used for the conversion of solid wax into liquid wax. The heat supplied to water at its boiling point is used for the conversion of liquid water into gaseous steam. Hence the thermometer is not able to register a raise of temperature. The heat supplied to

a body at the change of state level and not registered by the thermometer is called the latent heat. It is hidden in the substance itself.

If the heat is latent at the melting point, it is called the latent heat of fusion. It is the quantity of heat required to convert 1 gm. of the substance at the melting point to the liquid state at the same temperature. Likewise, the heat hidden at the time of boiling point of the liquid is called the latent heat of vaporisation. It is the quantity of heat required to convert 1 gm. of liquid at its boiling point into the vapour at the same temperature.

The latent heat of fusion of ice at $0°C$ is 80 calories. The same 80 cal. of heat will be given out if 1 gm. of water is converted into ice at $0°C$. The latent heat of vaporisation of steam at $100°C$ is 539 calories. The same quantity of heat will be given out when 1 gm. of steam is converted into water at $100°C$.

Know Yourself

1. During summer you have noticed that huge ice blocks are carried through the streets on cycles. The ice blocks do not melt much on the way. But a small piece of ice will soon melt and cannot be carried far. The larger the block of ice greater will be the quantity of heat required to melt it. For each gm. of ice, 80 cal. of heat is required to melt and there will not be sufficient heat to melt the huge block of ice.

2. When hot water is poured on the skin, the injury caused is not much. But when the skin comes into contact with the steam, the injury is greater than that of the hot water. Why? When 1 gm. of steam touches the skin, it condenses to form water at $100°C$ releasing 539 cal. of heat. Then this water comes to the temperature of the body, say $37°C$ thereby releasing further 63 cal. of heat. On the whole 602 calories of the heat is given to the body. But when hot water at $80°C$ falls on the body, it merely releases 43 calories of heat while it comes to the body temperature of $37°C$. Hence the injury caused by the skin coming in contact with steam is greater than that of the hot water alone.

Questions

1. Name the two types of effects caused by heat on a body.

2. Can there be a change of temperature when a solid is melting ?

3. Why does the temperature remain the same until all the solid is melted ?

4. What is meant by latent heat ?

5. Name the two types of latent heat.

6. What is the quantity of heat required to melt 1 gm. of ice into water at $O°C$?

7. What is the quantity of heat required to convert 1 gm of water into steam at $100°C$?

8. How is that a huge block of ice can be carried to a far distance while a small piece cannot be ?

9. Why is the injury caused by steam is greater than that of hot water alone ?

15. VAPOUR PRESSURE

When liquids are heated, they become vapour. The gaseous state of the liquid is called the vapour. But there is a difference between vapour and gas.

Vapour Gas

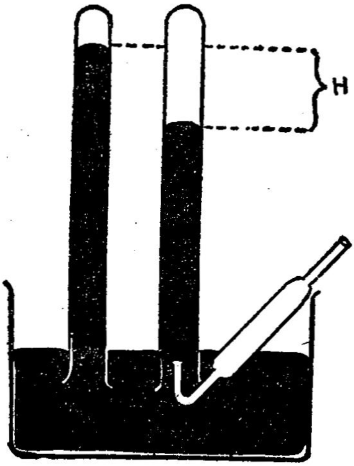
When the pressure over the vapour of the liquid is increased, they are converted into liquid again. But to convert a gas into a liquid, it is not sufficient to increase the pressure alone, but simultaneously the temperature has to be reduced. Hence we can safely say that those matter which are liquified on mere application of pressure are termed as vapours and those which

are liquified by applying pressure and lowering the temperature are called gases.

You know that water from the sea, lakes and tanks evaporate to become clouds and later they condense to form rain. Likewise, petrol or ether kept in an open vessel soon disappears into the air. Hence it is understood that evaporation does not take place merely at a particular temperature alone but takes place at all temperatures. When liquids boil, it is known as rapid evaporation.

Vapour Pressure

We can demonstrate from the following experiment that vapours exert pressure. Arrange two barometer tubes in the same mercury trough. The mercury levels in both the tubes will be the same indicating the atmospheric pressure. Introduce a small quantity of ether by means of a bent pipette into any one of the barometers. Ether ascends up the column of mercury and soon reaches the Torricelli vacuum, where it becomes vapour. You will note that soon the mercury level in that particular barometer is depressed. The difference between the levels of mercury in both the barometers indicate the pressure of the vapour. It is the vapour pressure of ether. Introduce some more ether and you will see that the mercury level is still depressed indicating that the vapour pressure increases.

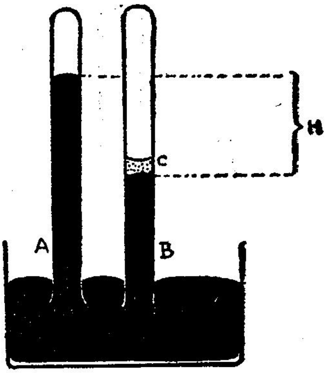


Vapours exert pressure
Fig. 50

Saturated Vapour Pressure

Set up two barometers as stated in the above experiment. Introduce ether in one of the barometers till a small quantity

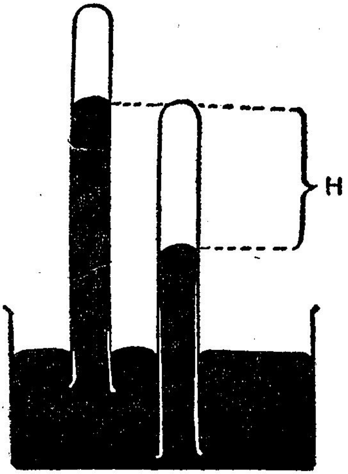
of ether remains as liquid above the mercury level. The addition of ether beyond that stage does not result in vaporisation. The space above the mercury level in the barometer is said to be saturated with ether vapour. The difference in mercury levels between the two barometers indicate the saturated vapour pressure of ether.



Saturated Vapour Fressure
H-indicates Saturated Vapour Pressure
Fig. 51

Experiment I Saturated Vapour Pressure is independent of its Volume

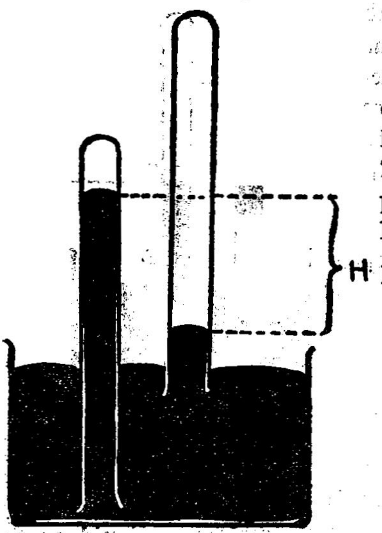
Set up two identical barometers in the same trough of mercury. In one of the barometers, introduce ether until its saturated vapour pressure is formed. In this situation a small quantity of ether will remain as liquid on the mercury surface. The space above the mercury level to the top of the barometer tube is the volume of the saturated ether vapour. Now lower the barometer tube containing the ether vapour into the trough. You will notice that the mercury rises up in the tube thereby reducing the space above. That is, the volume of the ether vapour now becomes less. But note the difference between the levels of mercury in the two barometers. It remains the same. That is, the pressure has not changed.



Saturated Vapour Pressure is independent of Volume
Fig. 52

Now raise the barometer tube containing the ether vapour. Carefully see that the open end of the tube does not come out

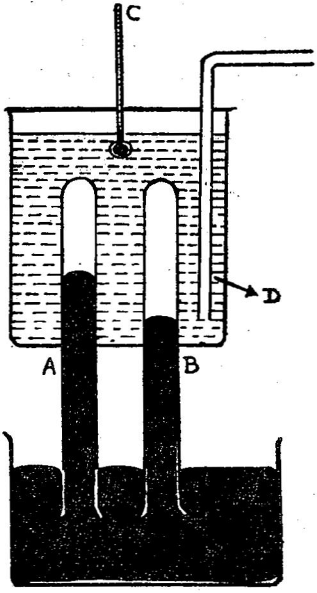
of the trough. You will see that the level of mercury in the tube falls, thereby increasing the space above the mercury level. In other words, the volume of the ether vapour has increased. Notice the difference between the two mercury levels. It remains the same. That is, the saturated vapour pressure does not obey Boyle's law.



Saturated Vapour Pressure is independent of Volume
Fig. 53

Experiment II Saturated Vapour Pressure varies with Temperature

Set up the two barometers in the same mercury trough. Enclose the tubes in a chamber containing water. Insert a thermometer to measure the temperature of the water bath. Introduce ether in one of the barometer tubes so that saturated vapour is formed. Note the saturated vapour pressure of ether by finding the difference of the mercury levels in the two barometers.



Saturated Vapour Pressure is proportional to the Temperature
A; B–Barometer C–Thermometer, D-Water bath
Fig. 54

Add ice cubes to the water in the tube and observe what happens. As the temperature is lowered, some of the ether vapour is condensed into liquid. The difference between the mercury

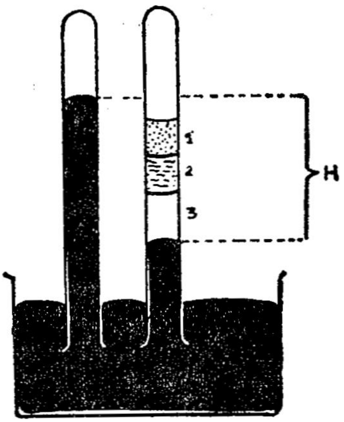
levels becomes less and less indicating the effect of lowering of temperature on the pressure of the vapour.

Then add steam to the water bath. The temperature of the water bath increases. As the temperature increases, the liquid ether above the mercury level vaporises and pushes the mercury level down. In other words, increase of temperature registers an increase of vapour pressure.

From the above experiments, we understand that the vapour pressure is directly proportional to the temperature.

Experiment III The total vapour pressure of more than one liquid enclosed in a place is the sum total of their individual vapour pressures

Initially determine the saturated vapour pressure of ether alcohol and petrol separately. As in the previous experiment, set up the two barometers in a mercury trough. Introduce the liquids ether, alcohol and petrol to get the saturated vapour pressure of each in one of the barometers. Note the difference of levels of mercury in the barometers. It gives the pressure of the liquids in total. Add the in dividual vapour pressures of the liquids already found. It will be found to be equal to that of the pressure now found in the barometer. Hence we understand that the total vapour pressure is the sum total of the Individual pressures of the each of the liquids.



Sum total of Saturated Vapour Pressures of more than one Liquid

Fig. 55

Dalton's Laws of Vapour Pressures

From the experiments conducted, we arrive at certain laws which go by the name of **Dalton.** The laws are as follows :

1. The saturated vapour pressure of a liquid does not obey Boyle's law.

2. The saturated vapour pressure of a liquid is proportional to the temperature.

3. The combined saturated vapour pressure of more than one liquid, that do not react, is the sum total of the saturated vapour pressures of the individual liquids.

4. Saturated vapour pressure of a liquid does not vary because of the presence of any other liquid that does not react with it.

5. Saturated vapour pressure of different liquids will be different.

Questions

1. What is meant by vapour ?

2. What is the difference between vapour and a gas?

3. How will you show that vapours do have pressure?

4. Define saturated vapour pressure.

5. How will you prove that the saturated vapour pressure is not dependent on its volume?

6. How will you know that the vapour pressure is the saturated vapour pressure of a liquid?

7. Describe an experiment to show that the saturated vapour pressure is proportional to the temperature.

8. What will be the total vapour pressure of liquids that do not react with each other enclosed in a space amount to?

9. State the Dalton's laws of vapour pressure.

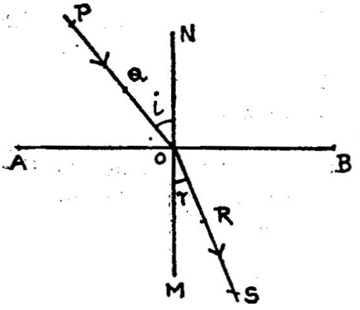
10. Show that the vapour pressure of different liquids differ.

11. Ether is introduced in a barometer. How will you know that the vapour pressure is unsaturated or saturated?

IV. Light

16. REFRACTION—RECTANGULAR SLAB

In the seventh standard you have read about refraction of light and its effects. The depth of a well appears to be less and the stick in water appears to be bent due to refraction of light. You have read about many more phenomena taking place due to refraction of light.



Path of a Ray in two Media

Fig. 56

Look at Fig. 56. The line *AB* represents the boundary of the two media-air and water. A ray of light *PQ* is obliquely incident on the surface *AB* at *O*. The light is travelling from air to water. The path of the ray is denoted by line *PQRS*. Line *PQ* represents the path of light in the air while line *RS* represents the path in water. Draw a perpendicular line to *AB* at *O* and name it *MON*. Line *PQ* is called the incident ray and line *RS* is called the refracted ray. The angle of incidence is *PON* and the angle of refraction is *SOM* respectively known as the angle '*i*' and angle '*r*'. It will be noticed that the path of the ray is bent towards the normal

when it goes from air to the water. Hence the angle of refraction is less than the angle of incidence.

Laws of Refraction

(1) When a ray of light passes from one medium into another, the incident ray, the refracted ray and the normal at the point of incidence all lie on the same plane and on either side of the surface separating the two media.

(2) For a given colour of light passing from one medium to another, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. It is called the **refractive index** of the second medium and denoted by the letter 'μ'

The second law of refraction is called the **Snell's law**

Refractive Index

You have read in the seventh standard that the refractive index of glass is the ratio between the actual depth and the apparent depth.

i.e. $$\mu = \frac{\text{actual depth}}{\text{apparent depth}}.$$

It is also the ratio of the velocity of the light in air to the velocity of light in glass.

i.e. $$\mu = \frac{\text{velocity of light in air}}{\text{velocity of light in glass.}}$$

Likewise, in this lesson, you are going to read that the refractive index of glass is the ratio of the sine of the angle of incidence to the sine of angle of refraction.

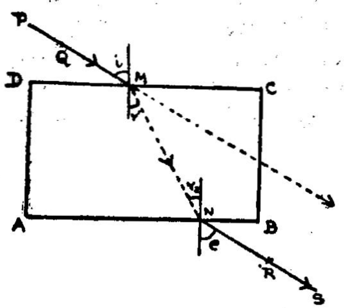
$$\mu = \frac{\sin i}{\sin r}$$

To determine the Refractive Index of Glass or to verify Snell's law

Rectangular Prism

Place a rectangular prism on a white sheet of paper placed on a drawing board. Trace the edge of the prism and name it *ABCD*. On the side of *CD* draw a perpendicular

line at any point M. Then draw an incident ray at an angle of 30° to the perpendicular line. Fix two pins P and Q vertically one behind the other. Look at the pins from the side of AB. Fix two more pins at R and S one behind the other such that all the four pins lie in a straight line without parallax error. Mark the positions of the pins and join them with a straight line. The line RS meets he side AB at N. Join MN inside the rectangular prism $ABCD$. In the diagram PQ is the incident ray, MN is the refracted ray, and RS is the emergent ray. The angle made by the incident ray PQ with the normal at M is the angle of incidence 'i'. The refracted ray makes two angles with the normals one at M and the other at N. The angles are respectively denoted as r_1 and r_2. The angle made by the emergent ray is called the angle of emergence 'e'. [In the figure we see that the emergent ray is parallel to the incident ray. If suffers a lateral displacement.]



Refraction in Rectangular Slab
Fig. 57

Repeat the experiment with the angle of incidences as 35°, 40° etc., and find the corresponding refracted angles. Find the sine value of angles of incidence and refraction from the Clark's table.

Find the value of $\sin i/\sin r$ for each experiment. You will see that the ratio is constant.

No.	Angle of incidence i	$\sin i$	Angle of refraction	$\sin r$	$\frac{\sin i}{\sin r}$
1.	50	0·7660	30	0·5000	1·532
2.	55	0·8192	32	0·5299	1·546
3.					
4.					
5.					

Do it Yourself

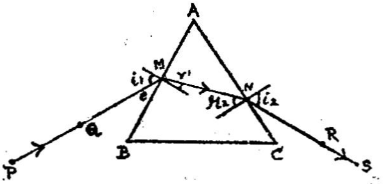
Determine the refractive indices of different oils using a hollow glass slab. Find also the refractive indices of the same bought from different shops. Compare the refractive indices and the refractive index of the oil obtained from one shop, if much different from the standard value, means that it is adulterated.

Questions

1. Define incident ray, refracted ray.
2. How will the path of the ray bend when a ray of light passes from a rarer medium to a denser medium?
3. The ray passing from air to glass suffers displacement but not deviation. Explain.
4. State the laws of refraction.
5. State Snell's law.
6. Describe an experiment to find the refractive index of glass.
7. How will you verify Snell's law?
8. The angle of incidence of a ray of light passing from air to glass is 60°. Its angle of refraction in the glass is 35°. Calculate refractive index of glass.
9. The angle of incidence of a ray of light passing from air to water is 50°. Its angle of refraction in water is 35°. Calculate refractive index of water.
10. Draw a neat sketch of the path of the ray of light moving from air to glass to air.

17. REFRACTIVE INDEX—TRIANGULAR PRISM

In the last lesson you have read about the refraction of light in a rectangular glass prism. You have read that the ray of light suffers a displacement but not deviation. In this lesson you will read about the refraction of light through the triangular prism.



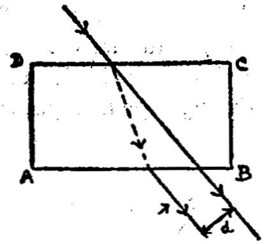
Refraction in Triangular Prism
Fig. 58

Place the given prism on a sheet of paper and trace the edges. Name the edges as *ABC*. On the side of *AB* at any point, *M*, draw a perpendicular. Make an angle of 30°to the normal drawn. Fix two pins at *P* and *Q* one behind the other. Look at the pins from the side of *AC*. Fix two more pins at *R* and *S* one behind the other such that the four pins lie on the same straight line. Mark the positions of the pins and remove them. Join the points. The line *RS* meets the side *AC* at *N*. Join *MN*. The line *PQ* is the incident ray. The line *MN* is the refracted ray and line *RS* is the emergent ray. The angle made by *PQ* at *M* with the normal at *M* is the angle of incidence i_1. The refracted ray *MN* makes two angles-one at *M* and the other at *N*. They are called the refracted angles r_1 and r_2. The line *RS* makes an angle with the normal at *N* and is called the angle of emergence i_2.

Increase the angle of incidence to 35°, 40°, 45° and so on and repeat the experiment. Find for each angle of incidence the corresponding refracted angle. Find the sine values of the angles of incidence and the angles of refraction. Calculate the ratio of sin *i* to sin *r*. You will find that the ratio is a constant.

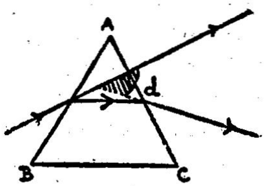
There is a slight difference between the path assumed by the light ray while passing through the rectangular glass and the triangular glass prism. In the rectangular glass slab, the light ray after passing through the glass suffers a displace-

ment. But in a triangular prism, the light ray after passing through the glass suffers deviation. In order to find the angle of deviation, project the incident ray *PQ* and the emergent ray *SR* backward. They will intersect at a point. The angle between the two is the angle of deviation *d*.



Displacement due to Refraction
d–lateral displacement
Fig. 59

In a triangular prism, the angle of deviation goes on decreasing for the increase of angle of incidence. For a particular angle of incidence, the angle of deviation is minimum, after which the angle of deviation increases with the increase of the angle of incidence. The deviation which is the minimum is called **the angle of minimum deviation.** A graph can be drawn between the angle of incidence on the *X* axis and the angle of deviation on the *Y* axis. The graph will be a parabola. Apart from the deviation, the light passing through a triangular prism shows another phenomenon called **dispersion** about which you will read more in the tenth standard.



Deviation due to Refraction
Fig. 60

Know Yourself

Refractive index of glass is calculated by the formula $\mu = \frac{\sin i}{\sin r}$ In a triangular prism in the angle of minimum deviation position the refractive index can be calculated using the formula

$$\mu = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

. Here *A* denotes the angle of the prism and *D* denotes the angle of minimum deviation.

(2) The refractive index varies, with the colour. Hence, when the composite white colour is passed through the triangular prism, each colour is deviated depending on its refractive index, resulting in the dispersion of the colour.

Questions

1. Describe the experiment to find the refractive index of triangular glass prism.
2. What is meant by the angle of deviation?
3. In a triangular prism, the ray of light suffers deviation and not displacement. Explain.
4. What is the relationship between the angle of incidence and the angle of deviation.
5. Define angle of minimum deviation.

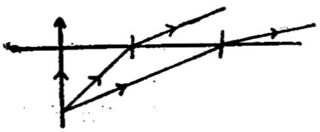
18. TOTAL INTERNAL REFLECTION

In summer, during the day, walking along a straight road, you will see water on the road ahead of you. As you near the place, the water will shift its place and again appear at a distance. This phenomenon is called mirage. How does it happen ?

You have seen the small red light disc fixed to the rear of your cycle. It shines brightly in the night when light falls on it. Let us learn about all these things in this lesson.

Let us consider a ray of light passing from a denser medium to a rarer medium. If it goes in a straight line perpendicular to the surface of the medium, it suffers no refraction. When the incident ray makes an angle with the surface, the light ray suffers refraction. It is found that the angle of refraction is greater than the angle of incidence, as the ray is passing from a denser medium to a rarer medium. Let us increase the angle of incidence gradully and you will see that the angle of refraction also increases correspondingly. For a particular

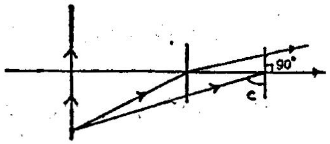
angle of incidence, the refracted ray just graces the surface of separation of the two media. That is, the angle of refraction at this stage is 90°. The angle of incidence for which the angle of refraction is 90°, is called the **critical angle** of that medium. When a ray of light passes from a denser to a rarer medium, the angle of incidence for which the angle of refraction is 90° is called the critical angle. This is represented by the letter '*C*'.



Angle of Refraction increases with increase of the Angle of Incidence

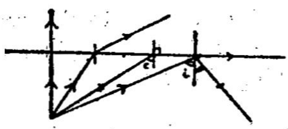
Fig. 61

What will happen if the angle of incidence is increased beyond the critical angle? Let us consider that also. If the angle of incidence of the light ray passing from a denser medium to a rarer medium is greater than the critical angle of that medium, then the ray is not refracted but turned back in the same medium. That is, the ray of light suffers reflection at the surface of the denser medium. This phenomeon is called **total internal reflection.** The line which separates the two media acts as a reflecting surface in this case.



Critical Angle

Fig. 62



Total Internal Reflection

Fig. 63

Conditions for Total Internal Reflection to take place

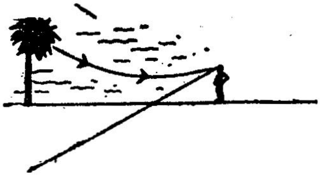
1. Light should pass from a denser medium to a rarer medium.
2. The angle of incidence should be greater than the critical angle of that medium.

Effects of Total Internal Reflection

Mirage

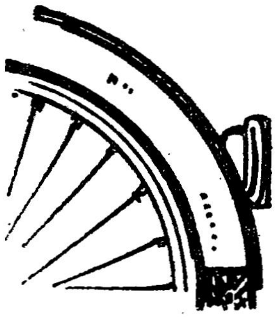
1. On hot days the atmosphere above the ground is not uniform. Several layers of temperature zones are

formed with the high temperature at the bottom near the ground and less and less of temperature as we go up. Hence a ray of light coming from a tree top or a building will always be moving from a denser to a rarer medium. As it passes towards the ground, it suffers refraction at every layer and at a particular layer, its angle of incidence will be greater than the critical angle of that medium. At this layer, the light ray will undergo total internal reflection and after successive refractions reach the eye of the observer. To the observer, it will appear as though the light is coming from the foot of the tree or the building. Hence an image will be built up in his mind as if he is seeing an inverted picture of the tree or the building. He also sees directly the tree or the building and its reflection at the same time. So he gets the idea that water is there at the foot to the tree or the building.



Mirage
Fig. 64

2. The Small Red Light at the rear of the Cycle and Total Internal Reflection



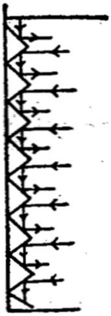
Rear side Reflector of a Cycle
Fig. 65

Remove the protective glass of the red light fixed to the cycle at the rear end and run your finger on the red disc. You will notice several humps and bumps on it. If you have a close look at it, you will come to know that it is made up of several small triangular prisms. The prisms are 45° (total internal reflection) prisms. When a light ray falls on it, the ray undergoes total internal reflection twice and turned back in the same direction from which it came.

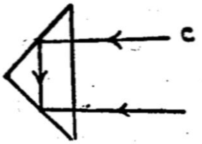
3. Glittering of the Diamond

Diamond is got from the mines. Raw diamond will not glitter. But when its sides are cut and polished, it glitters

brilliantly. A light ray entering the diamond undergoes

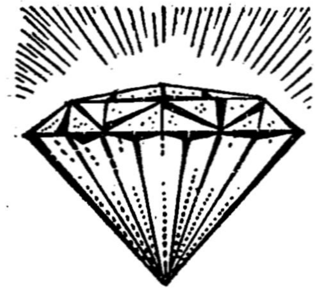


Refraction taking place at the rear side reflector of a Cycle
Fig. 66



Light ray turned back in the direction from which it came
Fig. 67

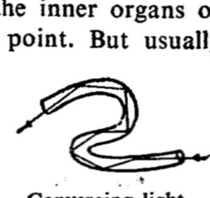
several reflections inside the diamond itself and comes out after total internal reflection. Hence it is bright. Critical angle for diamond is 24°.



Glittering of the diamond
Fig. 68

4. Total internal reflection prisms are made use of in periscopes, binoculars, reflecting telescopes, range finders. If plain glass mirrors are made use of,the image becomes dull after some time due to loss of coatings of the reflecting surfaces. But total internal reflection prisms collect all the light rays and send them back after reflection without any loss. Hence the image formed is bright.

5. To get a bright spot of light to see the inner organs of the body, the light is made to converge at a point. But usually the converging of light rays also result in the converging of heat rays, which cause damage to the parts. Hence transparent bent rods are made use of, where in the light undergoes total internal reflection without converging the heat rays.Hence doctors find it easy to use it to view the parts of eye and inner parts of the ear and the mouth.



Converging light without heat
Fig. 69

Questions

1. How will the angle of incidence and the angle of refraction be formed when light passes from denser to a rarer medium?

2. Define critical angle.

3. What do you call the incident angle in a denser medium for which the angle of refraction is 90°?

4. If the angle of incidence is greater than the critical angle, how will the path of the ray be formed when it passes from a denser to a rarer medium?

5. Describe with a neat sketch the phenomenon of total internal reflection.

6. What are the conditions for the total internal reflection to take place?

7. What are the effects of total internal reflection?

8. What do you mean by mirage? Explain.

9. Draw a neat sketch to show how the light ray is bent 90° using 45° prism.

10. Draw a neat sketch to show how the light ray is bent 180° using a 45° prism.

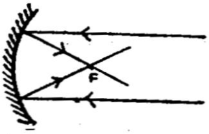
11. Why does a diamond glitter?

12. Why do telescopes and periscopes have total internal reflecting prisms in the place of plane mirrors?

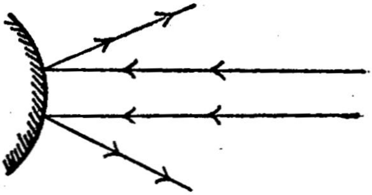
19. SPHERICAL MIRRORS

In the lower classes you have read about plane mirrors and the laws of reflection. In this lesson you will learn more about the effects of curved surfaces of mirrors called spherical mirrors.

If the reflecting surface of the mirror is plane, it is called the plane mirror. If the reflecting surface is curved either inward or outward, it is called the spherical mirror. The spherical mirrors can be either concave or convex.



Concave Mirror
Fig. 70



Convex Mirror
Fig. 71

Concave mirrors are those mirrors, whose reflecting surfaces are concave,as that of the front side of a ladle. Convex mirrors are those mirrors, whose reflecting surface is convex as that of the back side of the ladle.

Property of a Concave Mirror

When a parallel beam of light falls on the concave mirror, the light rays, after reflection, usually converge at a point,

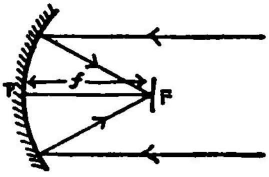
Names to be remembered in a Concave Mirror

Pole of the Mirror : The centre of the concave mirror is called the pole of the mirror.

Principal Axis : It is an imaginary line drawn perpendicular to the surface of the concave mirror at the pole of the mirror. The principal focus and the centre of curvature of the mirror lie on this line.

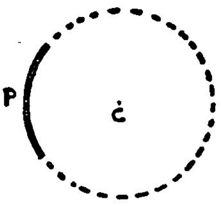
Principal focus (*F*) **:** It is a point on the principal axis of the concave mirror where all the parallel beam of light converge after reflection.

Focal Length (*f*) **:** It is the distance between the pole of the mirror and the principal focus.



Principal Focus
Fig. 72

Centre of curvature (*C*) **:** It is the centre of the sphere of which the concave mirror forms a part.



Centre of Curvature
Fig. 73

Radius of curvature (*R*) **:** It is the radius of the sphere of which the concave mirror forms a part.

In general, the radius of curvature of the concave mirror is twice that of the focal length. If '*R*' is the radius of curvature and '*f*' the focal length, then

$$\boxed{R = 2f}$$

Image formed by a Concave Mirror

There is a lot of difference between the image formed by the plane mirror and the concave mirror. The image formed by the concave mirror depends on the position of the object placed in front of the mirror. Hence the image may vary from a virtual image to an enlarged, real image.

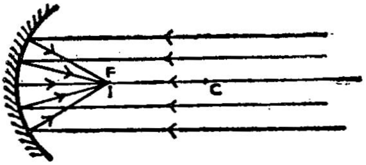
Fixing the Position of the Image of the Concave Mirror

In order to draw the image of the object formed by a concave mirror, the following points have to be borne in mind :

1. Light rays drawn parallel to the principal axis of the mirror after reflection will always pass through the focus.

2. A light ray drawn through the focus of the concave mirror will always be parallel to the axis after reflection.

3. The light ray through the centre of curvature of the mirror will always trace back the same path after reflection.



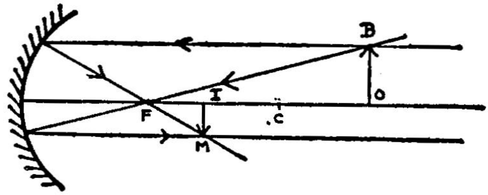
Object-at Infinity
Fig. 74

1. When the Object is at Infinity

A point image is formed at the principal focus of the concave mirror.

2. When the object *OB* is placed beyond the Centre of Curvature

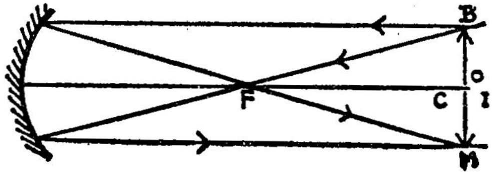
A real image (*IM*), inverted, diminished in size is formed between the focus and the centre of curvature.



Object beyond *C*
Fig. 75

3. When the Object *OB* is placed at the Centre of Curvature

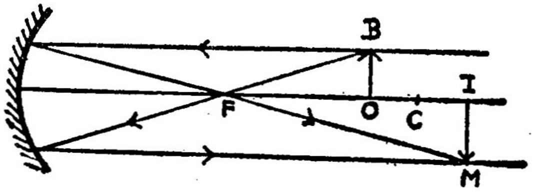
A real, inverted, image *IM* of the same size of the object is formed at the centre of curvature of the mirror itself.



Object at *C*
Fig. 76

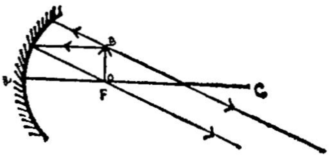
4. When the Object is placed between the Focus and the Centre of Curvature

A real, inverted, enlarged image is formed beyond the centre of curvature of the mirror.



Object between F and C
Fig. 77

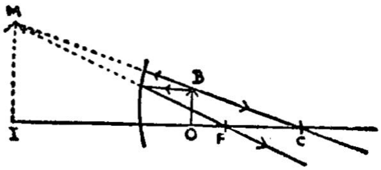
5. When the Object is placed at the Principal Focus



Object at the Principal Focus
Fig. 78

An image will be formed at infinity as the rays are rendered parallel after reflection.

6. When the Object is placed within the Focal length of the Mirror



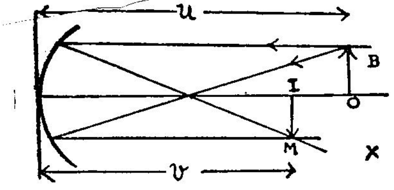
Object between Pole and Focus
Fig. 79

A virtual, enlarged, erect image is formed with in the mirror.

To determine the Focal Length of the Concave Mirror by *u-v* method

Fix the given concave mirror to its stand. From the centre of the mirror, mark on the table distances 30, 35, 40 cms. Place a lighted candle in front of the mirror at 30 cm. distance. Move a white screen in front of the mirror back and forth and fix it at a place where a clear image, either

big or small, is formed. The distance between the mirror and the candle is called 'u' and the distance between the mirror and the screen is called 'v'. Measure the distance of 'v'. Move the candle to the next mark and find the position of the image. By moving the candle to the successive marks, find the corresponding positions of the image.

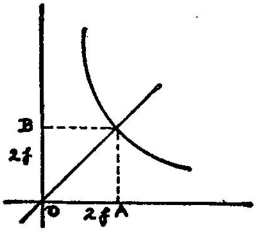


Determining 'f' $u-v$. method
Fig. 80

Measure the value of 'v' in each case and tabulate the results. Using the formula $f = \frac{uv}{u+v}$, the focal length of the given concave mirror can be calculated.

No.	u cms	v cms	uv	$u+v$	$f=\frac{uv}{u+v}$ cms
1.	30	60	1800	90	20
2.	35	46·6	1631	81·6	19·98
3.	40	40	1600	80	20
4.	45	36	1620	81	20
5.	50	33.3	1665	83·3	19·26

Average 19·85 cm.

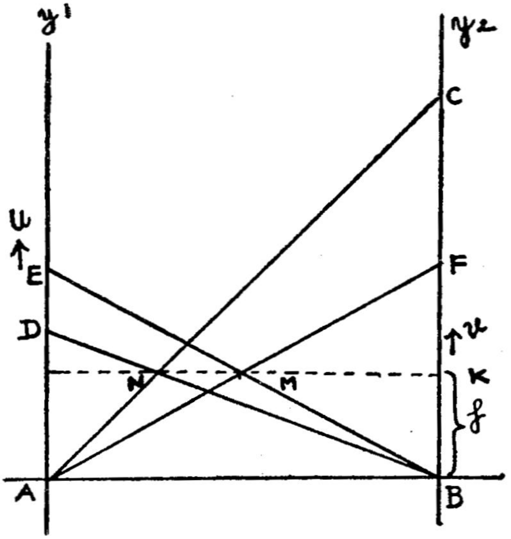


$u-v$ graph
Fig. 81

To determine the Focal Length of the Concave Mirror by the Graphical Method

Repeat the u, v method once again and tabulate the values of u and v. Then plot the values of u on the X axis and the values of v on the Y axis. A curved line similar to the diagram shown in Fig. 81 will be obtained. Bisect the angle between the X and Y axis. The bisector cuts the graph at a point. The co-ordinates of the point of

interesection gives the value of R (radius of curvature) which is twice that of the focal length. (i.e.) $OA = OB = R = 2f$. Half of the value found is the focal length of the concave mirror.



Determination of focal length
Fig. 82

For Thought

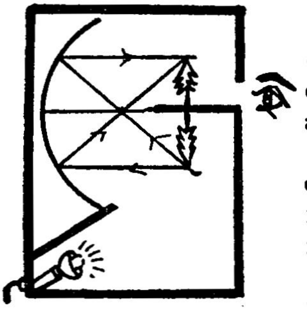
The graphical method can slightly be altered in the following manner. After finding the value of 'v' and 'u' the following procedure may be followed :

Instead of the conventional X, Y axes, draw two Y axes on X axis. Leave a space of 5 cms in between the Y axes, (The space between the lines is not a criterian). Then plot the values of u on one of the Y axes and the values of v on the other Y axis. Join one of the values of u to the origin of the other Y axis. Join the corresponding v value to the origin of the other Y axis. You will find that both the lines will intersect at a point. You will also find that for all values of u and v, lines drawn intersect at points which lie on a line parallel to

the X axis. The height of the point of intersection of the lines is the focal length of the concave mirror. Can you explain how?

(Hint: Apply similar triangle principle and deduce the formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$.)

Magic Flower Vase

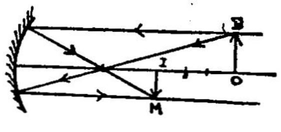


Magic Flower Vase
Fig. 83

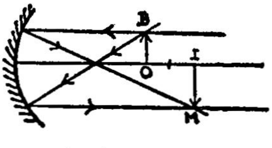
Take a box of convenient size and fix into it a concave mirror of suitable focal length. Fix a colourful flower bunch upside down away from the direct vision of the observer and at the centre of curvature of the mirror. Arrange for a source of light which illuminates the flowers only and not the mirror as shown in Fig. 83. When you see through the hole in front of the mirror in the box, you will see the bright flower bunch. If you try to catch it, you may not be able to do so because it is only the image of the flower you are seeing.

Conjugate Foci

Place a lighted candle beyond the centre of curvature of the concave mirror. A real, inverted, diminished image is formed between the focus and the centre of curvature. Arrange a



Conjugate Foci
Fig. 84



Conjugate Foci
Fig. 85

screen to catch the image. Then interchange the positions of the candle and the screen. You will notice that again a clear image is formed on the screen. The positions of the image and the object are called conjugate foci positions.

Image formed by a Convex Mirror

The reflecting surface of the convex mirror is curved outward. That is, the convex surface of the mirror is polished to reflect light. The light rays falling on it will be diverged after

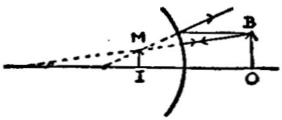


Image in a Convex Mirror
Fig. 86

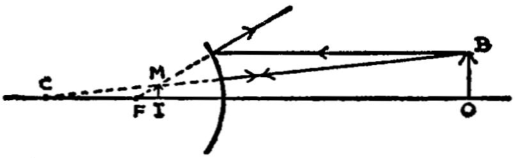


Image in a Convex Mirror
Fig. 87

reflection. The focus of the convex mirror lies at the back of the mirror and hence it is said to be virtual.

Whatever be the position of the object in front of the mirror, a virtual, erect, diminished image is always formed behind the mirror.

Uses of the Spherical Mirrors

Concave mirror

1. It is used as a reflector in microscopes, telescopes and film projectors.
2. It is used to construct magic flower pot.
3. Dentists make use of it to view the interior of the mouth and the back side of the teeth.

Convex mirror

It is used as a rear view mirror in the automobiles.

Questions

1. What is the difference between a plane mirror and a spherical mirror ?

2. What are spherical mirrors ?

3. Define a concave and a convex mirror.

4. Draw neat sketches to show the path of the ray after reflection in a (a) concave (b) convex mirror.

5. Define pole of the mirror, the principal focus and the radius of curvature of a concave mirror.

6. Define principal axis, focal length and the centre of curvature.

7. What is the relationship between the focal length and the radius of curvature ?

8. What are the conditions to draw the geometrical figures in finding the position of the image formed by a concave mirror ?

9. Write down the characteristics of the image formed by a concave mirror when the object is beyond the centre of curvature.

10. Draw a neat sketch to show the formation of images when the object is beyond the centre of curvature.

11. When does the concave mirror form a same size real image ?

12. When does a concave mirror form a virtual enlarged image ?

13. When does a concave mirror form a diminished, inverted, real image and enlarged, inverted, real image ?

14. Draw neat sketches to show the formation of images for objects at different positions in front of the concave mirror.

15. Describe an experiment to determine the focal length of a concave mirror.

16. Describe the graphical method to determine the focal length of a concave mirror.

17. With a neat sketch explain the magic flower pot.

18. Explain conjugate foci.

19. Draw a neat sketch to show the formation of an image in a convex mirror.

20. What are the uses of the spherical mirrors?

21. In a concave mirror an image is formed at 30 cms. when an object is formed 20 cms. before the mirror. Calculate its focal length.

22. In a concave mirror whose focal length is 15 cms. an image is formed at a distance of 24 cms. from the mirror. What is the distance of the object from the mirror?

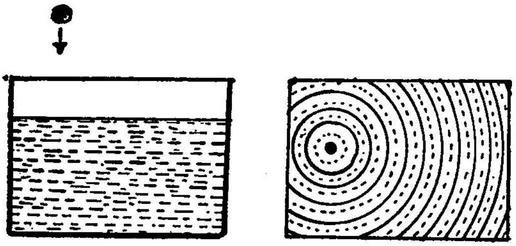
V. Sound

20. TRANSVERSE AND LONGITUDINAL WAVES

Put small pebbles one after another into a trough of water. Observe what happens. As the pebbles drop into the water, small waves are generated.

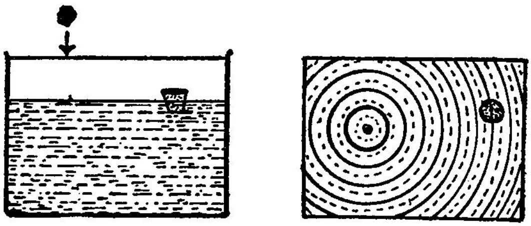
Float a small cork in a trough of water and repeat the above experiment. Observe carefully what happens. The

pebbles generate small waves which spread in all directions of the trough. As the waves approach the cork, it merely moves



Waves in Water
Fig. 88

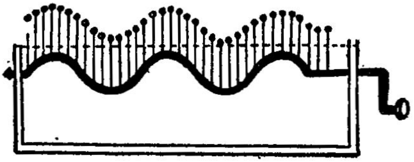
up and down. The waves passing through the cork do not make it move sidewards, but only make it move up and down. For our observation it appears that a wave is generated at the point where the pebble is dropped into the water. The waves move out in all directions. But for the up and down motion of the cork, it appears to be stationary. What do you understand from this?



No sideward movement of the Cork
Fig. 89

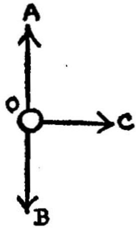
The water molecule is disturbed at the point where the pebble is dropped. This disturbance is passed onto the next molecule and the next molecule in succession. Hence the molecules of the water will be moving up and down, but not all of them in the same direetion. When some molecules are moving up, some will be moving down and at a particular time the molecules will be in different positions. This disturbance caused in the water molecules gives us an impression of the wave propagation.

In order to understand the situation described earlier, a wave generator can best be made use of. It consists of a long rod bent in the shape as shown in the Fig. 90. Rods of equal length carrying small spheres at one end are placed to stand vertically on the long rod. When the rod is rotated, those near the humps are raised and those rods near the troughs are



Wave Generator
Fig. 90

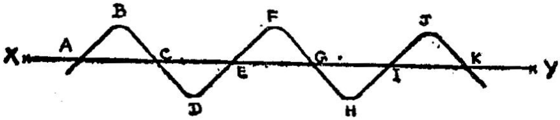
lowered. As it happens in rapid succession, an illusion of wave motion is created.



Transverse Wave Motion
Fig. 91

Observe carefully the wave motion. The spheres in the rod move up and down. But the wave appears to move from left to right or right to left. That is, the wave propagation takes place in a direction perpendicular to the direction of the vibration of the particles. This kind of wave pattern is called **transverse waves.**

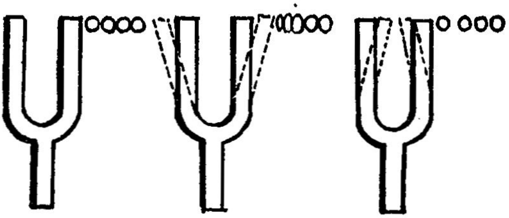
The pattern of the transverse waves looks like a sine curve about which you will learn more in the higher classes.



Transverse Wave
Fig. 92

In Fig. 92 *ABCDE* is, called the wave. The part *AE* is called the wave length. *EFGHI* is called the second wave.

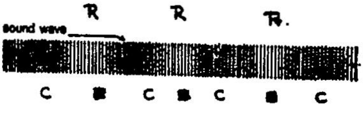
Its length is *EI*. In the wave *ABCDE* part *ABC* is called a **crest**, and the part *CDE* is called the **trough**. Hence we understand that a wave consists of a crest and a trough. These crests and troughs are generated in rapid succession and this movement is called wave propagation. The number of crests and troughs made in one second is termed as the **frequency** and the distance covered by the wave in one second is called the **velocity of the wave.**



Vibration of a Tuning Fork

Fig. 93

Vibrating particles can also set up another kind of wave pattern. Observe the vibration of the parts of a tuning fork. It moves from left to right. As it moves to the right, the pressure on the air molecules on that side increases or in other words, those air molecules are compressed. Then the fork moves to the left, thereby reducing the pressure on the air molecules. In other words, the molecules are rarefied. This kind of **compression** and **rarefaction** take place in rapid succession resulting in a type of wave propagation called **longitudinal waves.**

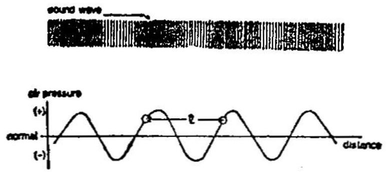


Longitudinal wave
R–Rarefaction
C–Compression
Fig. 94

Fig. 94 represents the pattern of a longitudinal wave. Here *R* stands for rarefaction and *C* for compression.

Transverse waves and longitudinal waves are similar in basic principles. The crest in the transverse waves is similar

to the compression and the trough corresponds to the rarefaction,

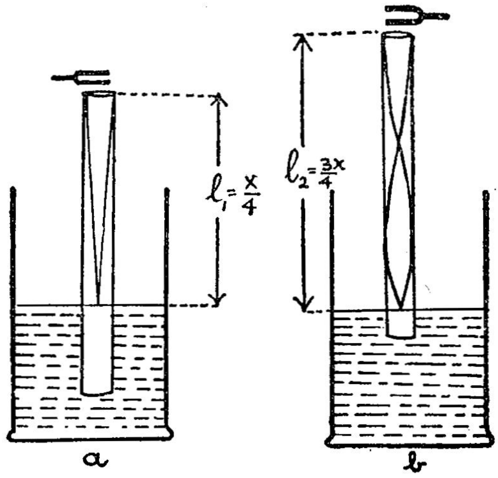


Longitudinal and Transverse Waves
Fig. 95

To determine the Velocity of Sound in Air

Sound is propagated with a particular speed in air. The velocity of sound is much less than the velocity of light. Sound travels at the rate of 330 meters per second in air.

You have already read about resonance in the 8th standard. Have you seen the experiment with a long jar full of water, and the tuning fork to demonstrate the principle of resonance in air? We can make use of the same experiment now to find the velocity of sound in air.



Velocity of Sound-determination
Fig. 96

Fill a tall jar with water up to half its height, Take a long glass or a metal tube open at both ends. Stand it erect in water.

Strike a tuning fork of a known frequency and hold it at the open end of the tube. Slowly raise both the tube and the tuning fork. At a particular height, you will hear a loud sound of the tuning fork due to resonance. Note the height of the tube above water level. Go on increasing the height of the tube till you will hear once again a loud sound due to resonance. Note the height of the tube above the water level. Repeat the experiment with different tuning forks of different frequencies and tabulate the length (l_1) and the length (l_2) of the resonating columns.

The first resonance was heard at a place $\frac{1}{4}$th of the wave length of the sound produced.

Hence $l_1 = \frac{1}{4}\lambda$ (where λ = wave length).

In the second case, the resonance was heard at $\frac{3}{4}$th of the wave length of the sound produced.

Hence $l_2 = \frac{3}{4}\lambda$.

Subtracting one from the other, we get

$$l_2 - l_1 = \frac{3}{4}\lambda - \frac{1}{4}\lambda = \frac{1}{2}\lambda$$

from which we get $\lambda = 2(l_2 - l_1)$.

The velocity of sound in air is given by the formula $v = n\lambda$. where 'n' is the frequency and λ is the wave length. But we know that $\lambda = 2(l_2 - l_1)$.

Hence $v = n \times 2(l_2 - l_1)$

or $v = 2n(l_2 - l_1)$.

If n is in hertz (Hz) and λ in metres (m), then the unit of v will be m/sec.

Tabulation

No.	Frequency of the tuning fork used n (Hz)	Resonating column		$v = 2n(l_2 - l_1)$ (m/sec)
		First length l_1 (m)	Second length l_2 (m)	
1.				
2.				
3.				
4.				
5.				

Average

Questions

1. How will you show that in wave propagation, particles vibrate at a particular place· but do not move sidewards ?
2. How are waves propagated ?
3. Describe the action of a wave machine.
4. What are transverse waves ?
5. What are longitudinal waves ?
6. What is the difference between the transverse waves and the longitudinal waves ?
7. Explain : crests and troughs.
8. What do you mean by wave propagation ?
9. Write a short note on longitudinal waves.
10. How will you show that basically the transverse any longitudinal waves have no difference ?
11. What is the velocity of sound in air?
12. How will you determine the velocity of sound in air?
13. Write down the formula for calculating the velocity of a wave.
14. Draw neat sketches to illustrate transverse and longitudinal waves.

21. SONOMETER

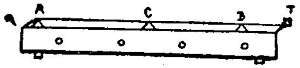
Laws of Stretched Strings

Have you attended a music concert? Have you seen the different kinds of musical instruments made use of in the concert ? the veena, the violin, the guitar, the mandalin, the bulbulthara and a few of the stringed instruments are used in a musical concert. The size of the instruments remaining the same, they are able

to produce different kinds of notes in the instruments. How do they do it? When the finger touches the string in the lower end or the upper end of a veena, why does the note change? Let us learn about all these in this lesson. In all the stringed instruments mentioned just now, tempered wires of different thickness are stretched across a wooden box lengthwise. Arrangements are given to tighten or loosen the strings thereby increasing or decreasing the tension of the strings. These strings are known as 'stretched strings'. Let us learn the laws that govern these stretched strings.

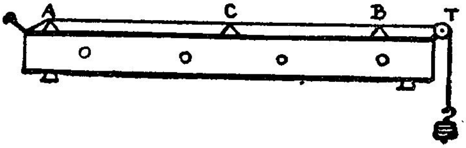
Sonometer

The instrument made use of to study the behaviour of stretched strings is called the sonometer. The figure illustrates the construction of a sonometer.



Sonometer
Fig. 97

It is a metre long empty wooden box. A hook is fixed at one end and a tight screw is fixed at the other end. A tempered metal wire is tied to the hook and the other end of the wire is attached to the screw. On turning the screw in the required direction we can increase or



Sonometer
Fig. 98

decrease the tension in the string. The wire passes over two fixed (*AB*) knife edges at the extreme ends of the box. A third movable (*C*) knife edge is provided in between. By moving the knife edge *C* the length of the vibrating string can be altered.

Laws of Sonometer or Laws of stretched strings

Law 1. *Tension remaining constant, the frequency of a vibrating stretched string is inversely proportional to the length of the string. That is, if 'n' is the frequency and 'l' is the length of the vibrating string, then*

$$nl = \text{constant}.$$

Law 2. *Length remaining constant, the frequency of the vibrating stretched string varies directly as the square root of the tension acting on it.*

$$(i.e) \quad \frac{\sqrt{T}}{n} = constant.$$

Law 3. *The frequency of a vibrating string varies inversely as the square root of the mass per unit length (linear density) of the string.*

$$[i.e] \quad l\sqrt{m} = constant.$$

Verification of the Laws

Law 1. $n \times l$ = constant.

Arrange the sonometer on the table with a particular tension. Select five tuning forks of frequencies 256, 320, 426, 480 and 512. Prepare a few light paper riders and place them on the string. Strike the tuning fork of frequency 256 and place it on the sonometer box. Adjust the movable knife edge in such a way that the string picks up the vibration of the tuning fork. This will happen when the vibrating string attains a particular length. At that time the paper riders perched on the string will fly off. Note the length of the string. Use the other tuning forks one by one and by the same method, find the corresponding lengths of the vibrating string. Tabulate the results. Find the values of the products of frequency (n) and length (l). In all the experiments, it will be found that the product remains the same.

Table

No.	Frequency of the tuning fork n Hz.	Length of the vibrating string l cm.	$n \times l$
1	256	70	17920
2	280	64	17920
3	320	56	17920
4	512	35	17920

Law 2. $\frac{\sqrt{T}}{n}$ = constant. Though it is possible to find the ratio $\sqrt{T}$ and n, it will be a difficult process for adjusting the tension for a particular length of the vibrating string every time the tuning fork is changed. Hence to facilitate easy experiment, the frequency is kept constant in the place of length and the variation of length for tension change is calculated, from which the ratio $\frac{\sqrt{T}}{l}$ is proved to be constant. This is an indirect way of proving the law.

Arrange the sonometer on the table and select a tuning fork with a particular frequency. Find the length of the vibrating string for the tension. Then increase the tension and find again the length of the vibrating string for the new tension. Likewise go on increasing the tension and each time find the length of the vibrating string. Tabulate the results and find the value of the $\frac{\sqrt{T}}{l}$. In all the cases, it will be found that the ratio is a constant.

Table

No.	Tension T *kg.*	Length of vibrating string l *cms.*	$\sqrt{T}$	$\frac{\sqrt{T}}{l}$
1.				
2.				
3.				
4.				
5.				

Law 3. $l \times \sqrt{m}$ = constant

This law is also best proved in the indirect way. Select different metal wires of known density. Fix them to the sonometer one after the other and subject them to the same tension.

For each string find the length of the vibrating string for a particular frequency of the tuning fork. Tabulate the results and calculate the value of $l \times \sqrt{m}$. It will be found that it remains constant.

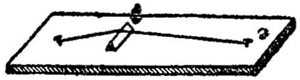
Table

No.	Density of the string m	Length of vibrating string l	$\sqrt{m}$	$l \times \sqrt{m}$
1.				
2.				
3.				
4.				
5.				

Do it Yourself

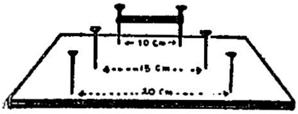
I. Single Strand Instrument

Take a wooden board of 50 cm. length and 5 cm. breadth. Fix a length of tempered steel wire to the board with nails as shown in the figure. Place a strip of metal to act as a knife edge. Place your finger on the string on the other side of the knife edge and pluck it. You will be able to produce certain notes after some practice.



Single Strand Instrument
Fig. 99

II. Different notes are produced for different tension



Note depends on length and tension
Fig. 100

Arrange pairs of nails set apart at distances 10 cm. 15 cm. and 20 cm. on a wooden board. Then stretch a rubber band over the set of nails 10 cm. apart. Pluck it and listen to the note produced. Then transfer the rubber band to the pairs of nails 15cm, and 20 cm. apart and repeat the experiment.

You will find that the note produced each time is different. It varies with tension.

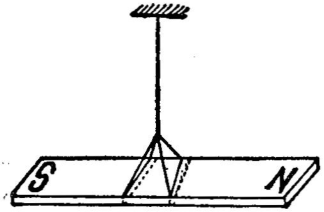
Questions

1. What is the use of a sonometer?
2. Draw a neat sketch of a sonometer.
3. Write a short note on sonometer.
4. State the laws of sonometer.
5. What is the relationship between the frequency and the length of a vibrating string when the tension is unaltered?
6. What is the relationship between the frequency and the tension of vibrating string of constant length?
7. When strings of different densities are subjected to the same tension, how will the length and the frequency of the vibrating strings vary?
8. How will you verify the first law of stretched strings?
9. Describe an experiment to verify the second law of stretched strings.
10. How will you verify the relationship between the mass per unit length of the string and the length of the vibrating string?
11. A sonometer wire resonates at 72 cm. of length with the tuning fork of frequency 288 Hz. What will be the length of the same vibrating string for the same tension if the frequency of the tuning fork is 432 Hz.
12. The tension of a vibrating string of frequency 256 Hz. and length 70 cm. is 5 kg. Find the length of the same string for the same frequency if the tension is increased to 7·2 kg.

VI. Magnetism and Electricity

22. Magnetic field

Suspend a bar magnet by an inelastic thread. After a few oscillations, it comes to rest in a fixed direction. It assumes the same position even after it is disturbed. One end of the bar magnet points to the north pole of the earth and the other end points to the south pole of the earth. We say that the bar magnet aligns itself with the magnetic field of the earth.



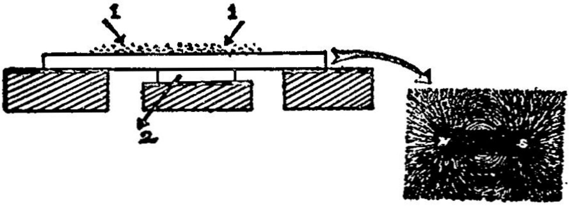
Bar Magnet Suspended by a String
Fig. 101

Bring a small magnetic compass near any one of the poles of the bar magnet. You will see that the needle is deflected. Move the compass in and around the bar magnet far and near. You will see that the needle is deflected or affected by the bar magnet within a space around the magnet in all directions. Beyond the limit of that space, the magnetic needle is unaffected by the bar magnet. Hence we understand that the field of the magnetic force is felt within a limit around the bar magnet.

What do you infer from the above experiment? We understand that there is a definite space around the bar magnet and within the boundary of the magnetic force, the effect is felt. This boundary depends on the strength of the bar magnet. Weaker magnets have a smaller boundary and stronger ones have wider boundaries. The space around the bar magnet where the effects of magnetic force will be felt is called the magnetic field. In order to know the magnetic field, the following experiments can be performed :

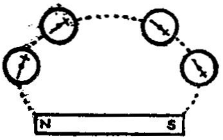
Place a square glass plate over a bar magnet. Fix a white paper over the glass and sprinkle lightly fine iron

powder, gently tap the glass plate and observe what happens. The iron filings arrange themselves in rows of lines around the



Magnetic Lines around a Barmagnet
1. Iron Powder 2. Magnet
Fig. 102

place where the bar magnet is placed. Each line of iron filings indicates the magnetic line of force of the magnet.



Drawing the Magnetic lines
F.g. 103

The same experiment can be repeated with a small magnetic needle. Then the actual lines can be drawn with a pencil on the white paper. How to do it ?

To draw the Lines of Force around a Bar Magnet

Fix a white sheet of paper on the table. Place a bar magnet at the middle of. the paper and trace its boundaries. Then bring a compass needle near one of the poles of the bar magnet. When the needle comes to rest, mark the tip of the needle on the white sheet or paper. Move the magnetic needle so that the other end of the magnetic needle comes just at the point marked previously. Now when the needle is at rest, mark the tip of the needle. Likewise go on marking points with the compass needle. You will see that the compass needle traces a path around the bar magnet. Join all the points. Move the compass needle to another position and begin to trace the path of the magnetic line as detailed before. Many lines can be drawn around the bar magnet. These magnetic lines are supposed to start from the north pole of the bar magnet and end with the south pole.

Hence arrow heads are placed in such a way to show that the lines emanate from the north pole of the bar magnet.

Properties of Magnetic Lines of Force

1. Magnetic lines are nothing but the locus of unit north pole around the bar magnet emanating from north pole to south pole. Hence no magnetic line will intersect with another.

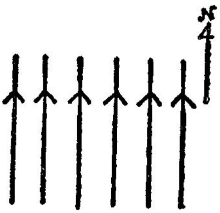
2. Lines of force start from north pole and end with the south pole.

3. Lines of force are found in all directions and in all planes of the bar magnet.

4. Magnetic lines of force crowd around the poles.

Magnetic Lines of Force of the Earth

Fix a white sheet of paper on the table. Place a small compass needle on the paper. Remove all magnetic substances from around the area where the expermient is conducted. The magnetic needle will point north-south direction. Mark on the sheet of paper the ends of the magnetic needle. Move the compass further such that one end of the needle comes exactly to the position of the mark already made. When the needle is at rest, mark the position of the other end of the needle. Likewise go on moving the compass marking the position of the end of the needle. You will see a straight line across-the sheet of paper.



Earth's Magnetic lines
Fig. 104

Place the magnetic needle at different points next to the line drawn and draw the lines of force as detailed before. Parallel magnetic lines of force will be found on the sheet of paper. This represents the earth's magnetic lines of force. It is supposed to start from the south direction of the earth and end at the north direction of the earth. Hence arrow heads are placed in such a way to show that the lines are moving from south to north.

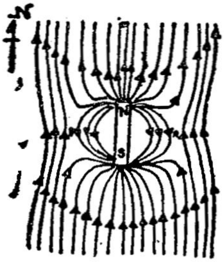
'he magnetic lines of force of the earth and the magnetic lines of force of a bar magnet will always interact.

Hence, when you try to draw the lines of force for both the bar magnet and the earth's magnetic lines of forces interesting patterns are formed. Let us try to draw the lines of force for a bar magnet when it is placed in the earth's magnetic field.

Mapping the Magnetic Field.

A. North Pole pointing North

Fix a sheet of white paper on a table Remove all magnetic substances from the vicinity of the table. First draw the magnetic lines of force of earth on the sheet of paper using a compass needle.



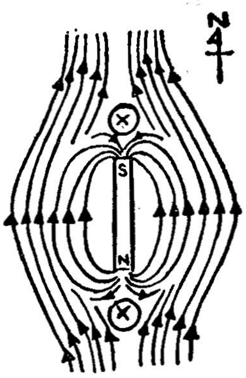
North Pole pointing North.
Fig. 104-A

Place the given bar magnet with it north pole pointing to the northern direction of the earth. Trace its boundary. Care should be taken to see that the position of the bar magnet is unaltered till the end of the experiment. Trace the lines of force around the bar magnet. Then place the compass needle on the edge of the papers and as detailed already, move the needle after marking the position of the needle. You will see that the path of the needle bends towards the bar magnet where the south pole is. Beyond the field of the bar magnet, the earth's magnetic lines of forces will be parallel. When it nears the bar magnet, it will bend towards the south pole. Hence somewhere in a line perpendicular to the axis of the bar magnet, there will be a point where the earth's magnetic field and the magnetic field of the bar magnet cancel each other. At that point, the magnetic needle of the compass will assume any direction showing that there is no magnetic effect there. This will be found on both sides of the bar magnet at equal distance from the bar magnet These points are called the null points.

When the resultant force of more than one magnetic force acting at a point is zero, then that point is called a null point.

B. North pole Pointing to the South of the Earth

Fix a white sheet of paper on a table and see that there are no magnetic substances in the vicinity of the table. Draw the magnetic lines of force of the earth in the sheet of paper using a small compass needle. Then place the given bar magnet in the middle of the paper with its north pole pointing to the south. Trace the boundary of the bar magnet. Using a small compass needle draw the magnetic lines of force around the bar magnet. You will see that the earth's magnetic lines of the force are parallel beyond the region of the bar magnet.



North pole pointing South
Fig. 104–B

But when they reach the bar magnet, the lines of force move away from the bar magnet. Hence a point is created in the line on the axis of the bar magnet where the effect of the bar magnet is cancelled by the earth's magnetic force. It is the null point and it is found on both sides of the bar magnet at equal distances from the poles on the line of the axis itself.

Having learnt about the mapping of the magnetic field, why don't you try for yourself the mapping of magnetic lines of force of two bar magnets with their like poles facing each other and unlike poles facing each other. Discuss the result with your teacher.

Questions

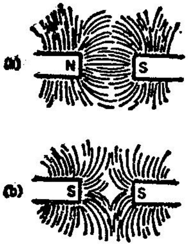
1. How do you know that the magnetic force exists around the magnet ?
2. Define magnetic field.
3. Describe a simple process of showing the magnetic lines of force around a bar magnet.

4. How will you draw the magnetic lines of forces around a bar magnet using a compass?
5. State the properties of the magnetic lines of force
6. Describe the process of drawing the magnetic lines of force due to earth's magnet.
7. How will you map the magnetic field of a bar magnet when its north pole points to (a) north (b) south of the earth?

23. STRENGTH OF A MAGNET POLE STRENGTH-MOMENT OF A MAGNET

Place a bar magnet on the table. Hold a piece of iron at a distance from any one of the poles of the magnet. You will feel the attraction of the magnet on the iron piece. If you let go the iron piece, it will move fast and stick to the magnet. Hold the iron piece at various distances around the bar magnet and see the force of attraction acting on it. See if the force of attraction on the iron piece is the same at all distances.

Bring the north pole of a bar magnet near the north pole of another magnet. You will feel the force of repulsion. Bring the south pole of the other magnet. You will feel the force of attraction. These experiments go to show that there is a force acting between the magnet and the iron piece or between the magnets. How will you measure the strength of that force?



Bar Magnets
Fig. 105

It was the scientist **Coulomb** who investigated about this and he came forward with a law known as the 'Inverse Square Law.' It is a very important law as far as science is concerned because it finds application in all branches of science namely light, sound, electricity, magnetism etc.

Inverse Square Law

The force of attraction or repulsion between two magnetic poles is directly proportional to the product of the pole strength of each of the magnets and inversely proportional to the square of the distance between the poles.

Pole Strength

If two magnetic poles of equal strength exert a force of one dyne in air or vacuum, when kept apart at a distance of 1 cm, the poles are supposed to have unit pole strength.

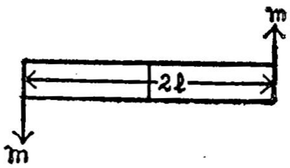
The force in dynes experienced by a pole of a magnet when kept at a distance of 1 cm. from a unit north pole is called the pole strength of the magnet. It is denoted by *CGS.* units.

If m_1, m_2 are the *CGS* units of the pole strengths of two magnetic poles and if they are separated by d cm. distance then the force F acting between them is given by the inverse square law.

$$F = \frac{m_1 m_2}{d^2} \text{ dyne.}$$

Moment of a Magnet

Suspend a bar magnet by an inelastic thread. Hold the bar magnet in such a way that its north pole points to east. When you release it, you will find that the bar magnet turns round and comes to its original position of north-south. The bar magnet turns because of the earth's magnetic force acting on it. The earth's magnetic force acting on the poles of the bar magnet constitute a couple and because of this coplanar forces, the bar magnet turns. If the pole strength is *m CGS* units and the length of the bar magnet is 2 l, then the moment of the bar magnet is given by the formula $M = m \times 2l = 2ml$ *CGS* units.



Moment of a Magnet
Fig. 106

Questions

1. Explain whether the magnetic force due to a magnet will be the same at all places around it.

2. Name the scientist who investigated about the pole strength of magnets.

3. State the law of inverse square.

4. What is meant by pole strength?

5. By what unit is the pole strength of a magnet denoted ?

6. What is the unit of magnetic force ?

7. Define magnetic moment.

8. Write down the formula for calculating the moment of a magnet.

9. Write down the formula for calculating the force acting between two poles of magnets kept at a distance.

0. If the pole strength of the two magnets are 4 *CGS* and 5 *CGS* units and if they are kept at a distance of 2 cm. apart, calculate the force acting between them.

1. Calculate the force acting between the two poles of magnets of pole strength 30 *CGS* and 40 *CGS* units and separated by a distance of 6 cm.

2. A magnet pole exerts a 2 dyne force on a unit north pole at a distance of 2 cm. Calculate the pole strength of the magnet.

13. Calculate the moment of a magnet of 10 cm. length and having a pole strength of 100 *CGS* units.

14. Calculate the moment of a bar magnet of 10 cms. length and having a pole strength of 25 *CGS* units.

24. PROPERTIES AND USES OF MAGNETIC SUBSTANCES

Touch all the objects you see in your house or school with a bar magnet. Note down your observations in a note book. You will see that iron, nickel and cobalt are attracted by magnets. Wood, paper, glass and cloth are not attracted. Materials attracted by magnets are called magnetic substances.

Collect some of the magnetic substances that you can find in your environment. Then test their capability to become a magnet. Steel becomes a magnet very easily. Moreover it becomes a permanent magnet. Mild steel also becomes a magnet but there is difference. It is a magnet as long as the magnet is in contact with it. It loses its magnetism when the magnet is removed. In other words, the mild steel becomes a temporary magnet. H ence there is difference in property in the magnetic substances also.

Permanence

Place a bar magnet underneath a sheet of glass. Place some nails over the glass. You will see that the nails are attracted by the magnet. If you move the magnet round, the nails will also follow the bar magnet. Though the nails and magnet are separated by glass, magnetic lines of force seem to pass through the glass sheet and reach the nails. If you make use of any other material other than the ferromagnetic substances, you will see the same effect. Hence materials like glass, wood etc., are said to have a property called permanence. It is the property of a substance which permits the passage of magnetic lines of force. It corresponds to the conductance of the electric circuit.

Ferro-magnetic Substances

Magnetic substances like, iron, cobalt etc., are called ferro magnetic substances. The magnetic strength of these materials increases upto a limit if the strength of the magnetic forces around it increases.

Susceptibility

A rod of steel placed near a bar magnet gets magnetised by induction. If the steel rod is replaced by a cast iron or soft iron, they also get magnetised. Test the magnetic strength attained by the three rods by a small compass needle. The amount of deflection of the needle will indicate the strength of the magnetic field of the steel, cast or soft iron rod. It will be found that the soft iron is strongly magnetised than the other two. Soft iron is thus found to be more susceptible to induced magnetism than steel. This property is known as susceptibility.

Retentivity

Wind insulated copper wire over a steel rod and pass an electric current. The steel rod becomes a magnet. Bring near it some iron filings and they adhere to it, showing that it has become a magnet.

Now repeat the experiment with soft iron. It also attracts the iron filings showing that it has become a magnet. Then switch off the current in both the steel rod and the soft iron rod. You will notice that almost all the iron filings clinging to the soft iron fall to the ground soon after the current is switched off. It indicates that the soft iron rod has lost its magnetic power. Whereas you will notice that some iron filings cling to the steel rod indicating that it has not lost all its magnetic power. Hence we can say that the retentivity of steel is greater than the soft iron. Under identical magnetising treatment, steel retains greater magnetism than soft iron. This property is called retentivity.

Those magnetic substances which have high retentive power are good for permanent magnets. Those which have less retentive power will be good for temporary magnets. The retentivity increases in the order iron-nickel-cobalt. Soft iron is more susceptible but less retentive and hence used for good temporary magnets.

In order to get high retentivity and susceptibility, alloys are made with steel and other magnetic substances. Alnico is

one type of that alloy which contains aluminium, nickel and cobalt mixed in certain proportion with steel. This alloy becomes a powerful magnet and retains its magnetic power to its full strength for a fairly long time of years.

Ticonal, Alcomax are other types of alloys used for preparing magnets. All these alloys are made of the same metals but they vary in ratio of their mixture.

Substances having large retentive power and susceptibility are called hard magnetic substances. These are made use of to make powerful magnets.

In order to make soft iron into a very good temporary magnet, 3·5% silicon is added to soft iron. This alloy is called Stalloy which is a perfect temporary magnet. Alloys of this type are called soft magnetic substances and they are useful only for making temporary magnets. Mumetal, Formolloy are other types of soft magnets used in making temporary magnets. They contain nickel and iron.

Uses of Magnets

1. Hip belts with magnetic ends are made use of to keep garments tight around the waist.

2. Torch lights are provided with magnets which attach themselves to the steel body of the vehicles leaving both the hands free to attend to the repairs at nights.

3. Magnets are made use of in cranes.

4. Powerful magnets are made use of to remove iron dust that has fallen into the eyes of the workers working in a factory.

Questions

1. What are magnetic substances ?
2. Give two examples for a magnetic substance.
3. What difference do you see in magnetic substances ?

4. Write a short note on permanence.

5. Give examples which have permanence and those which do not have this property.

6. What are ferromagnetic substances? Give examples

7. Define susceptibility and explain it.

8. Which metal is best suited for a powerful magnet?

9. Why should steel be used for a permanent magnet and soft iron for temporary magnet.

10. Write a short note on retentivity.

11. How are magnets made to have high susceptibility and retentivity?

12. Name the alloys made use of in powerful magnets.

13. What are hard magnetic substances?

14. What are soft magnetic substances?

15. Give two examples for soft magnets.

16. Explain :—
    Ticonal, Stalloy.

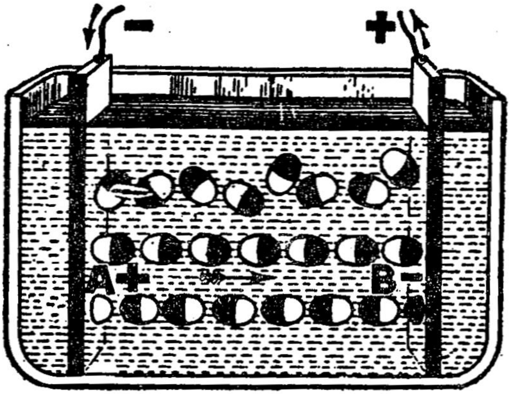
17. What is the use of mumetal?

25. FARADAY'S LAWS OF ELECTROLYSIS

In the seventh standard you have read about the changes that take place in a liquid when electricity is passed through it. You have also read about the scientist who investigated the effects of electricity in liquids. In this standard, you will learn more about electrolysis.

Solutions are ionised when a current is passed through it. These ions are responsible for the flow of electricity in solutions.

The metallic constituent of the solutions become ionised and move towards the negative pole of the voltameter. The metallic ion loses its charge and gets deposited in the negative electrode.

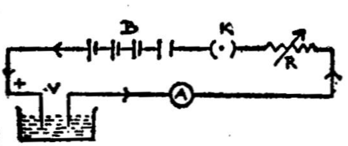


Ionisation of Solution
Fig. 107

This is the process of electrolysis. How much metal will be deposited within a particular time? Is there any relationship between the metallic deposit and the current or the time? Let us investigate these points in this lesson.

Metal deposit and Current—Relationship

Law I. When a constant current is passed through an electrolyte, the amount of metal deposited on the negative electrode is directly proportional to the time of passage of current.



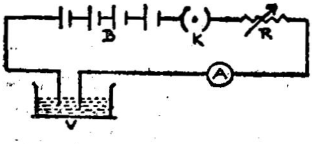
Faraday's I law–Experiment
Fig. 108

Arrange in series as shown in Fig. 108 a copper voltameter, rheostat, ammeter, switch and a set of battery. Adjust the rheostat in such a way that a current of 1 ampere flows through the circuit. Switch off the current and take away the negative electrode, cathode of the voltameter. Clean the plate brightly and find its mass. Replace the cathode to its original position

and switch on the current starting at the same time a stop clock. After passing the current for 15 minutes cut off the current and take out the cathode. Dry it and find its mass. Replace it in the same position and switch on the current. Now this time pass the current for 30 minutes. At the end of 30 minutes, take out the cathode and find its mass after drying it. In this way, go on repeating the experiment for increase of time and every time note the mass of the metal deposited. Tabulate the results. You will find that the ratio $\frac{m}{t}$ is a constant.

No.	Strength of current	Time of passage t × 60 secs	Mass of cathode $kg.$	Mass of metal deposited $=m\ kg.$	$\frac{m}{t}$
1.		0	m_1		
2.	1 amp	15	m_2	m_2-m_1	
3.		30	m_3	m_3-m_1	
4.		45	m_4	m_4-m_1	

Law II. The amount of metal deposited on a negative electrode during electrolysis is directly proportional to the strength of the current that passes through the electrolyte.



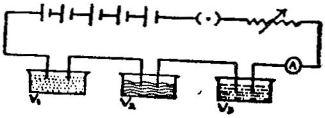
Faraday's II law-Experiment
Fig. 109

Arrange the electrical circuit as in the previous experiment. To begin with, find the mass of the cathode of the voltameter after cleaning and drying it. Adjust the rheostat so that 0·5 ampere of current passes through the circuit. Start a stop clock. After 15 minutes switch off the current and find the mass of the cathode after drying it. By adjusting the rheostat, repeat the experiment with increased current strengths of 0.6, 0.7, 0.8, 0.9

amperes and note down each time the mass of metal deposited on the cathode for the same time of 15 minutes. Calculate the ratio of $\frac{m}{i}$ and you will see that it is a constant.

No.	Time	Strength of current i (amperes)	mass of the cathode (kg)	Mass of metal $=m$ (kg)	$\frac{m}{i}$
1.		·0	m_1	-	
2.	15 mts	0·5	m_2	m_2-m_1	
3.		0·6	m_3	m_3-m_1	
4.		0·7	m_4	m_4-m_1	
5.		0·8	m_5	m_5-m_1	
6.		0·9	m_6	m_6-m_1	
7.					

Law III. When a constant current is sent through more than one electrolyte for a given time, the amount of metal deposited from each of the electrolytes is directly proportional to the electro chemical equivalent of the metal concerned.



Faraday's III law-Experiment
Fig. 110

Take three different voltameters and connect them in series along with the ammeter, rheostat, key and battery. Adjust the rheostat to send a current of 1 ampere through the circuit. Switch off the current. Take out the cathode of each of the voltameters used in the experiment and clean them. Replace them in the respective voltameters after finding their individual mass separately. Switch on the current and start a stopclock simultaneously. After allowing the current to pass through the electrolytes for 30 minutes, switch off the current. Take out the cathodes one by one and find the mass

of each after drying. You will see that the mass of metal deposited in each of the voltameters is proportional to their electro chemical equivalents.

The electro chemical equivalent of a metal is defined as *that mass of the metal deposited during clectrolysis when one ampere current passes through the electrolyte for 1 second.*

Let m be the mass of metal deposited on the cathode during electrolysis for a current of i amperes in a time 't' seconds. Then the ratio $\frac{m}{it}$ will be a constant and it is called the **electro chemical equivalent** of the metal. It varies from metal to metal. It is represented by the letter 'e.' $\frac{m}{it} = e$ or $m = eit$.

A flow of current 1 ampere in 1 second is called one coloumb. Hence $m = Q.e$. Electro chemical equivalent of a metal is denoted by the unit kg per coloumb (kg/coloumb).

Determination of Electro Chemical Equivalent of a Metal

Arrange a voltameter, a key, a rheostat and an ammeter in series as shown in Fig. 108. Adjust the rheostat to send 1 ampere current in the circuit. Switch off the current. Take out the cathode of the voltameter and clean it, wash it and dry it. Then find the mass of the cathode (m_1). Replace the cathode to its original position and switch on the current. At the same time start a stopwatch. Pass current through the circuit for 30 minutes. At the end of the time, switch off the current. Take out the cathode and dry it. (Care: It should not be washed now). Find the mass of the cathode (m_2). The difference in mass of the cathode plate ($m_2 - m_1$) gives the mass of metal deposited in 30 minutes. Tabulate the readings and calculate the mass of metal that will be deposited for 1 ampere current in one second. It is the electro chemical equivalent of the metal.

Strength of current passed	**= 1 ampere**
Time of passage	**= 30 mts**
	= 30 × 60 sec. = 1800 sec.

Mass of cathode in the beginning = m_1 kg.

Mass of cathode at the end of 30 mts = m_2 kg.

Mass of metal deposited = $(m_2 - m_1)$ kg

$(m_2 - m_1)$ kg. of metal is deposited by 1 ampere current in 1800 seconds. Then the mass of metal that would be deposited by 1 ampere current in one second

will be = $\frac{m_2 - m_1}{1 \times 1800}$ kg/coulomb.

On simplification of this equation, you will get the electro chemical equivalent of the metal.

For Thought

Visit the nearest electroplating workshop and observe how they do it. They use a weaker strength of current for a longer time for uniform coating of metal.

Collect materials for copper electroplating in your school laboratary and do the following experiments :

Select a suitable size of aluminium plate and coat it on both sides with a thin coating of wax. Use a sharp knife to etch out your name on the aluminium plate by scratching the wax out. You will see the metal in the place where the wax has been removed. Use it as the cathode of the copper voltameter and pass the current for 30 minutes. Then take the plate and remove the wax coating by a gentle heat. You will see your name carved on the aluminium plate with the metal copper in brown colour. You can use your imagination to produce new patterns.

Questions

1. What will happen when a current is passed through a liquid ?
2. State the I law of electrolysis.
3. How will you establish the relationship between the amount of metal deposited to the time of passage of current in electrolysis ?

4. State the II law of electrolysis.

5. How will you establish that the amount of metal deposited will be directly proportional to the strength of current passed in an electrolyte ?

6. State the III law of electrolysis.

7. Describe an experiment to prove the III law of electrolysis.

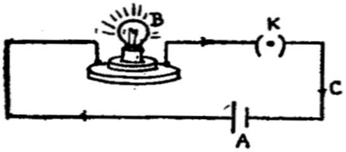
8. Define electro chemical equivalent of a metal.

9. Describe an experiment to determine the electro-chemical equivalent of a metal.

VII Atomic Physics

26. ATOMIC PHYSICS

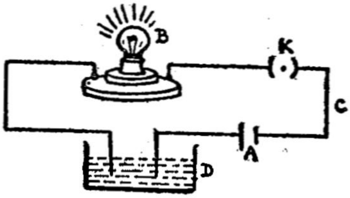
Connect a 2 *V* bulb in series with a torch cell along with a switch. When the switch is operated, current from the battery flows through the connecting wire to the bulb and it glows.



Electrical circuit
Fig. 111

Make the connections of a bulb, battery, switch and a beaker of distilled water as shown in Fig. 112. When you operate the switch, does the bulb glow? Why not? Think. Now add a few drops of dil. sulphuric acid to water and see if the bulb glows.

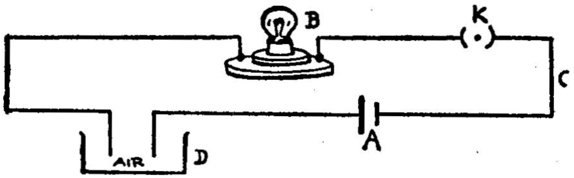
Now repeat the second experiment without water in the beaker. The beaker now contains air and see if the bulb glows.



Current through a Solution
Fig. 112

The copper conductor conducts electricity and so the bulb glows as soon as the switch is on in the first experiment. In

the second experiment, the distilled water is a non-conductor and so the bulb did not glow in the first instance. But, on



Current will not pass through Air
Fig. 113

adding a few drops of acid to water, it is made a conductor and so the bulb glows in the second instance. In the third experiment, the bulb does not glow at all. Why ?

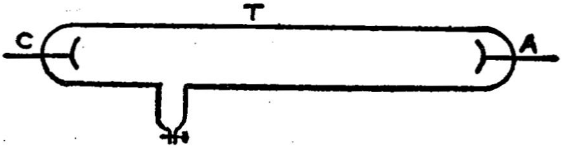
In the solids like copper, there are free electrons which are responsible for the flow of current in the conductor. When the free electrons rush towards the positive pole, we say the current is flowing.

The distilled water is a non-conductor of electricity. On adding a few drops of acid, ions of positive and negative charged particles are created in the water. The negatively charged ions rush towards the positive terminal which result in the flow of current.

Air is a bad conductor. Hence, in ordinary pressures, the current does not flow through air. It acts as an insulator. In this lesson, you will learn more about electricity flowing through gases under special cases and the effects of current passing through gases.

When a gas is ionised with ultra violet rays, ions are produced and to a certain extent, these ions will help the flow of current in the gas. But, when the pressure of the gas is reduced and a high voltage is applied to it, discharge of electricity will take place through the gas. The contrivance in which this phenomena takes place is called a discharge tube. Let us study about the discharge tubes in this lesson.

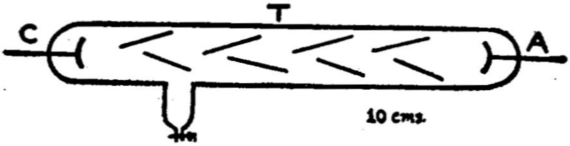
An ordinary discharge tube is like the glass tube shown in Fig. 114. It is a long tube of half a metre in length with a side tube at the end. The inside of the tube can be evacuated by connecting the side tube to a vacuum pump. Two metallic plates are fixed at each end of the glass tube. If the pressure of the air inside the tube is gradually reduced and a high voltage



Discharge Tube
Fig. 114

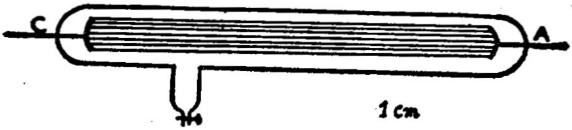
of 50,000 volts is applied between the terminals of the tube, a striking phenomena will be observed. The terminal connected with positive pole is called the anode and the terminal connected to the negative pole is called the cathode.

When the pressure of air is near 10 cm. of mercury, noisy flashes of light is seen in the discharge tube.



Discharge Tube – 10 cm. Pressure
Fig. 115

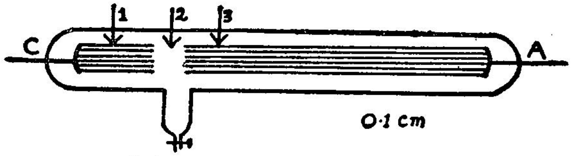
Go on reducing the pressure and when it is 1 cm. of mercury pressure, a violet glow is seen in the entire tube from the cathode to the anode. This glow is called the positive glow.



Discharge Tube–1 cm. Pressure
Fig. 116

When the pressure falls to 0·1 cm of mercury, a dark space appears between the cathode and the pink glow. This dark

space is called the **Faraday's dark space.** A light blue colour appears on the surface of the cathode and it is called the cathode glow.

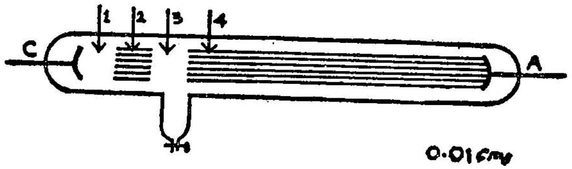


Discharge Tube – 0·1 cm. Pressure

1. Bluish Glow 2. Faraday's Dark Space 3. Positive Glow

Fig. 117

When the pressure is about 0·01 cm., another dark space appears between the cathode glow and the cathode plate. This dark space is called the **Crooke's dark space.** By this time you will observe that the length of the positive glow is considerably reduced.

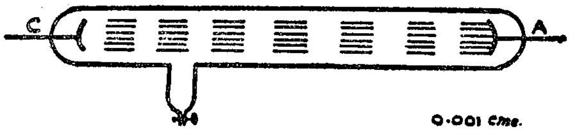


Discharge Tube – 0·01 cm. Pressure.

1. Crooke's Dark Space 2. Bluish Glow
3. Faraday's Dark Space 4. Positive Glow

Fig. 118

As the pressure of air inside the discharge tube comes to 0·001 cm., many Crooke's dark spaces appear in the tube. The positive glow is completely wiped out and at the same time, the glass walls near the cathode plate glow with blue



Crooke's Dark Spaces

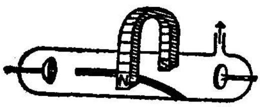
Fig. 119

or green colour. This effect is due to the invisible rays emitted by the cathode at that particular pressure of air. This invisible

ray is ejected out from the cathode and passes straight to the anode. These rays are found to be negatively charged and are called cathode rays.

Characteristics of Cathode Rays

1. These rays are ejected out of the cathode plate perpendicular to the surface of the plate.
2. These rays can be made to converge at the centre of curvature of a spherical surface.
3. Objects get heated up when these rays are allowed to fall on them.
4. These rays are propagated with nearly the velocity of light.
5. A small wheel placed in the path of the ray is made to rotate by the energy of the cathode rays.
6. These rays are affected by the magnetic field.



Cathode Rays affected by magnetic field
Fig. 120

7. These rays are also affected by the electrical field.
8. Gases get ionised when these rays pass through them.
9. Heavy metals produce X rays when these rays impinge on them.
10. These rays are nothing but the flow of electrons.

Know Yourself

It was **J. J. Thomson** who investigated about the nature of cathode rays. He found that the mass of this electron to be 9×10^{-31} kg. He found the charge to be $1{\cdot}6 \times 10^{-19}$ coulomb.

Questions

1. What is responsible for the flow of current through a conductor?
2. What makes the current to flow through distilled water with a few drops of acid?

3. Can electricity pass through air or gas at ordinary pressure? What should be done to make air a conductor ?

4. How will you make the electricity to pass through air under reduced pressure ?

5. Explain with a neat sketch the construction of a discharge tube.

6. Explain the happenings in a discharge tube under conditions of different pressures of air.

7. When does noisy splashes of light occur in a discharge tube ?

8. Write short notes on Faraday's dark space and Crooke's dark space.

9. When are the cathode rays produced in a discharge tube ?

10. What are the properties of cathode rays?

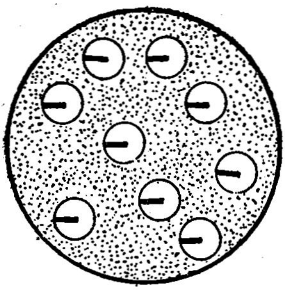
27. RUTHERFORD ATOM MODEL

You know that all matters consist of atoms. Do you know the structure of the atom? Let us read in this lesson how man ventured to predict the structure of an atom - the tiniest of the world.

The man's interest in knowing the internal structure of matters is as old as the world itself. Many thesis were advanced and discarded due to fresh knowledge and experience. It is not different with the history of man trying to understand the atom also. **J. J. Thomson, Earnest Rutherford, Neils Bohr** and scores of others involved themselves in unravelling the mystery of the atomic structure. Neils Bohr's explanation of atomic structure now holds good and is accepted everywhere.

In the beginning J. J. Thomson explained to the world about the structure of atom based on his experiments. Accord-

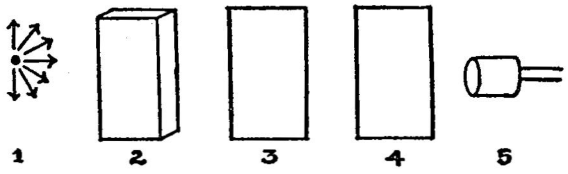
ing to him, the atom contained a positive electric fluid in which the electrons are strewn all over like the seeds embedded in a water melon.



Thomson Atom Model
Fig. 121

When an element is raised to the incandescent state, it emits a light of particular frequency characteristic of that element. When scientists theoretically calculated the frequency of the emitted light based on the Thomson's model, they found it varying with the experimental values. Hence they felt that the structure of an atom is not like the one envisaged by J. J. Thomson and discarded it.

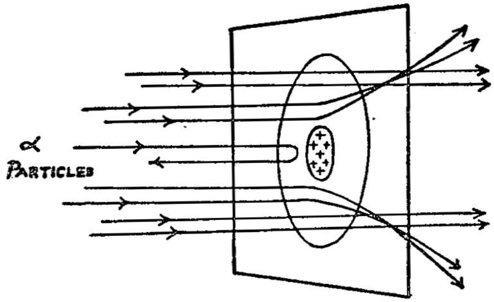
Then came Earnest Rutherford who predicted a more or less acceptable theory of the atomic structure. He said that the internal structure of an atom could be best understood only with the results of the impact of alpha particles with the atom. Hence he conducted innumerable experiments with the alpha particle collision with metal foils. He came out with a theory which explained to near perfection the structure of an atom.



Rutherford's Experiment on Atom
1. Alpha Particle Emitter
2. Lead Block to give narrow pencil of Alpha Rays
3. Thin Gold Foil 4. Phosphoroscent Screen 5. Microscope
Fig. 122

In his experiment, he used a thin gold foil and bombarded it, with alpha particles. To his surprise, he found that majority of the particles passed through the metal foil indicating a vacant space all round. But a few of them near the centre were deflected from their path and still a fewer of them were

returned in the same path in which they came. That is, they were deflected through 180°. From this he concluded that the atom consisted of a central mass of very small size with a strong positive charge. He called this the **nucleus**. The entire mass of the atom is concentrated in this area.



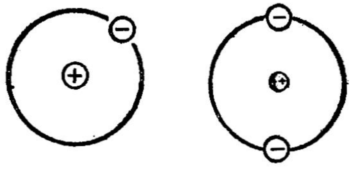
Bombardment of Gold Foil with α particle
Fig. 123

From his observations, Lord Rutherford enunciated a theory which is as follows :

All atoms consist of a nucleus of high positive charge. Electrons are found to move round this nucleus in circular orbits. The atom contains the same number of protons and electrons and hence the atom as such is electrically neutral and the mass of the atom is due to the nucleus only.

Even Rutherford's atomic model had some defects in the sense, that he was not able to predict the electron path or the number of electrons in the orbit.

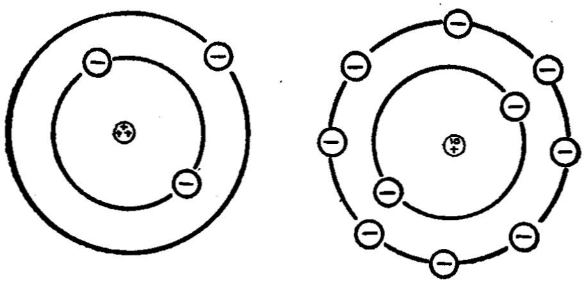
In 1913, Neils Bohr came out with a successful explanation of the atomic structure of hydrogen atom. He said that the hydrogen atom contains a nucleus with one proton and an electron which moved round the proton in a circular orbit. The proton has one electrical positive charge and the electron has one electrical negative charge. **G. N. Luis, Langmur, Bhari and**



1. Hydrogen Atom
2. Helium Atom
Fig. 124

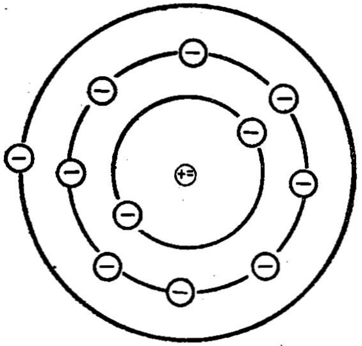
other scientists explained the electron orbits and the number of electrons that an orbit could contain at a time.

The number of electrons in an atom determines the number of electron orbits. Hence an atom may have electron orbits from one to any number depending upon the number of electrons. The maximum number of electrons in a shell can be determined from the formula $2n^2$ where 'n' is the number of the shell. For example, the K shell, which is number one shell, can hold $2(1)^2 = 2$ electrons. L shell which is two in number, can hold $2(2)^2 = 8$ electrons. The fourth shell N can hold $2(4)^2 = 32$ electrons in all.



1. Lithium Atom 2. Neon Atom

Fig. 125



Sodium Atom

Fig. 126

The electron in the outermost shell of an atom is responsible for chemical reaction. If the outer-most shell is complete

with the number of electrons it can hold. then that element becomes inert and does not react with other atoms. Neon, argon, krypton, zenon and radon are examples of this type where the outermost shells are saturated with eight electrons. They are called **inert gases.**

Discovery of Neutron

Inspite of the knowlege gained so far, the scientists were not able to explain in full the entire characteristic structure of atoms. There still existed a puzzle about the isotopes. They were not able to account for the difference in the mass of isotopes even though they contain the same number of protons. In 1932, **Chadwick** came out with an outstanding discovery of a particle which had no electrical charge but had the mass of, the protons. That particle was called the **neutron.** Hence he explained that neutrons are also found within the nucleus of an atom along with protons that accounted for the mass difference of the isotopes.

Atomic Number, Atomic Weight

Atomic number of the element is the same as the number of protons found in the nucleus of the atom. For example hydrogen which has one proton in the nucleus is assigned the atomic number as 1. The atomic number of helium is 2 which has 2 protons. Sodium is assigned atomic number 11 as it contains 11 protons.

Atomic weight is the total number of protons and neutrons present within the nucleus of an atom. Hydrogen has an atomic weight of 1 and Helium has an atomic weight of 4 as there are 2 protons and 2 neutrons in its nucleus. Uranium has 92 protons and 146 neutrons and so its atomic weight is 238 (92 + 146).

Structure of the Nucleus

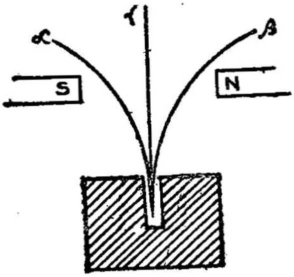
Aston, Chadwick, Anderson and others have investigated the structure of atomic nucleus. The nucleus contains protons and neutrons bound together with a mysterious force. You

will learn in more detail about the nucleus and its structure in the higher classes.

Radiations

Atoms are stable in general but there are a few atoms which are unstable. The unstable atoms always radiate energy and become lead atom at the end. Henry Bequerel investigated the unstable atoms and gave out a theory of radiation.

For his experiment he took a heavy lead box into which a small hole was drilled. A small piece of radioactive substance like radium is placed in the depth of the hole. An electrical field or a strong magnetic field is arranged above the hole. It was found that the radiation from the element split into three kinds of rays. One kind of ray was deflected by the positive charge of the electric field and was named as alpha ray. The second ray was attracted by the positive charge and was called the beta ray. The third ray was found to be unaffected by the electric and magnetic fields. These rays are called the gamma rays.



α, β and γ rays
Radioactivity
Fig. 127

Alpha Rays

These rays are called by Rutherford as fast moving helium nucleus. These rays contain 2 protons and 2 neutrons and they have a positive charge.

Beta Rays

These are high penetrating, fast moving electrons and have negative charge. The penetrating power of these rays is greater than alpha rays.

Gamma Rays

These rays are like *X* rays and have been termed as electromagnetic waves. They are of short wave length and have a greater penetrating power than beta rays.

Binding energy

Atomic mass units (*amu*) is used to denote the mass of protons and neutrons. It is of the order of $1{\cdot}66 \times 10^{-24}$

grammes. The total mass of the atom is made up of the mass of the individual particles contained in it. Scientists were baffled to find a difference in the mass as calculated and mass found by experiments. For example, the mass of oxygen which contained 8 protons and 8 neutrons differed from the experimental mass value by 0·13709 *amu*. Likewise the difference between the calculated value of mass and the experimental value of iron is 0·5288 *amu*. Why should there be a difference?. Where does the mass dissipate? **Einstein** came forward with an answer to all these questions. He said that mass and energy are two forms of the same matter and one can be converted into the other. Hence the difference in mass as found by the scientists is due to the fact that the mass is converted into energy to bind the protons and neutrons together. Protons which have the same charge will repel each other and they cannot be contained in a small space of the atomic nucleus. The fact that they are together is a proof of the force which keeps them intact in that space. The energy which keeps them together is called the binding energy.

Know Yourself

Atom in Greek means 'indivisible' but atoms have been split and atomic energy is being made use of.

The nucleus of the atom contains protons and neutrons. Protons are positively charged particles and neutrons are particles which have no charge. Then how is it that a disintegrating atomic nucleus emits beta rays which are negatively charged particles? Now they have found that the neutrons are not single particles. It is a mixture of (p) proton and (e^-) electron. During disintegration of the nucleus, negative electron (e^-) escapes as beta rays. Hence it is also found to be true that the number of protons in the nucleus increases after the disintegration of the nucleus.

'Mass and energy are two forms of the same matter' said Einstein and to prove his statement, he gave the formula $E=mc^2$, where E is the energy, m is the mass and c is the velocity of light.

Questions

1. Give the names of the scientists who investigated the structure of the atom.
2. Describe J.J. Thomson's atom model.
3. Why was Thomson's atom model rejected?
4. By whom was the current atomic structure given?
5. How did Rutherford show to the world that the nucleus lay at the centre of an atom?
6. Describe the atom model of Lord Rutherford.
7. Who discovered the nucleus in an atom?
8. By whom was the hydrogen atom explained correctly?
9. Who were the scientists who investigated the electron paths and neutrons?
10. What are electron shells?
11. Write down the formula for getting the number of electrons in a particular electron shell.
12. Draw a neat sketch of an atom which contains 23 electrons. Indicate therein the number of shells in the structure.
13. Draw a neat sketch of a neon atom.
14. Why do inert gases not react with other elements?
15. How are stable atoms formed?
16. By whom was the neutron discovered?
17. Write a short note on neutron.
18. Define atomic number and atomic weight of an element.
19. Explain with a neat sketch the structure of a nucleus.
20. Write a short note on radiation.
21. Name the scientists who investigated the atomic radiation.
22. Write short notes on alpha, beta, gamma rays.
23. Write a short note on binding energy of an atomic nucleus.

Part B-Chemistry

1. VALENCY AND CHEMICAL FORMULAE

Recall what you have studied in the lower classes. Matter can be broadly divided into three classes as elements, compounds and mixtures.

Elements

An element is a homogenous substance composed of the same kind of atoms and which cannot be further divided into simpler substances by any means. Just as the alphabets are fundamentals for all languages, elements are fundamentals for all substances. Iron, silver, hydrogen, oxygen, nitrogen and bromine are examples of elements.

Compounds

Compounds are homogenous substances formed by the combination of two or more elements combined in a fixed ratio by weight. Words are obtained in a language by the combination of letters. In the same way, compounds are formed by the combination of elements.

Compounds can be split into their constituent elements but the properties of compounds will be different from that of the elements contained in them.

Atom

An atom is the smallest, chemically indivisible particle of an element that can take part in a chemical reaction. Atoms cannot exist in a free state.

Molecule

A molecule is the smallest particle of an element or a compound which can exist in the free state and retain all its properties.

Atoms combine to form molecules. Molecules are usually divisible. For example, two hydrogen atoms combine with one oxygen atom to form a molecule of water represented by the formula H_2O. The formula SO_2 represents a molecule of sulphur-di-oxide formed by the combination of one sulphur atom with two oxygen atoms. A compound will contain the atoms of elements of which the molecule is composed in the ratio of small whole numbers.

Atoms of the same element may combine to form a molecule of that element. Hydrogen and oxygen atoms combine to form molecules of hydrogen (H_2) and oxygen (O_2) respectively.

A molecule of a compound contains atoms of different elements. But a molecule of an element contains atoms of the same element.

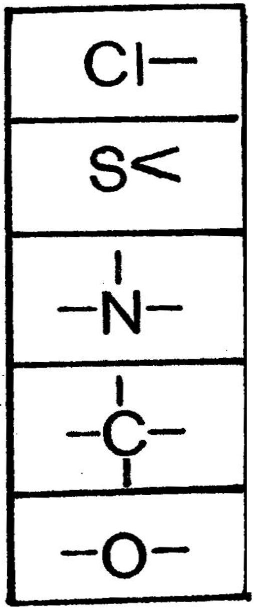
The compounds formed by the combination of atoms of chlorine, oxygen, nitrogen and carbon with hydrogen are given below.

Hydrogen chloride	HCl
Water	H_2O
Ammonia	NH_3
Methane	CH_4

In the compounds given above, hydrogen atoms combine with the atoms of other elements in a different ratio. Atoms of different elements do not combine with the same number of hydrogen atoms.

In hydrogen chloride molecule, one atom of chlorine has combined with one atom of hydrogen. One molecule of water contains two atoms of hydrogen and one atom of oxygen.

Three atoms of hydrogen combine with one atom of nitrogen to give one molecule of ammonia. Four atoms of hydrogen combine with one atom of carbon to give a molecule of methane.



Valency
Fig. 1

From this, it is clear that atoms of different elements do not combine with the same number of hydrogen atoms. **The combining capacity of one element with another element is called 'Valency'.**

To calculate the valency, hydrogen is taken as standard. The valency of hydrogen is taken as one. Based on this, the valency of an element is the number of hydrogen atoms with which one atom of the element would combine.

An atom of chlorine combines with an atom of hydrogen to form a molecule of hydrogen chloride. Hence the valency of chlorine is one. To form a molecule of water, an atom of oxygen has combined with two atoms hydrogen and so the valency of oxygen is two. Similarly an atom of nitrogen and an atom of carbon combined with three and four atoms of hydrogen to form ammonia and methane respectively and so the valency of nitrogen is three and that of carbon is four.

The valency of elements is known only when it combines with other elements. When they are in the free state as elements, the valency is not known.

All elements, particularly most metals, do not combine with hydrogen. So the valency of such elements cannot be measured with reference to hydrogen. How are we to measure the valency of such elements ?

Elements that do not combine with hydrogen combine with chlorine to form chlorides. You know that the valency of

chlorine is one. The valency of elements can be measured with chlorine as standard. For example, let us see the following compounds :

Sodium chloride	$NaCl$
Magnesium chloride	$MgCl_2$
Aluminium chloride	$AlCl_3$

An atom of sodium combines with an atom of chlorine to give a molecule of sodium chloride. And so the valency of sodium is one. Since an atom of magnesium and aluminium combine with two atoms of chlorine and three atoms of chlorine respectively, the valency of magnesium is two and that of aluminium is three. Now we can say that **the valency of an element is the number of chlorine atoms with which one atom of that element would combine.**

The valency of elements which do not combine with hydrogen or chlorine are calculated with oxygen atom as the standard. From the molecule of water (H_2O) you know that the valency of oxygen is two. So **the valency of an element can be defined as twice the number of oxygen atoms with which one atom of that element would combine.**

An atom of carbon combines with two atoms of oxygen to give a molecule of carbon-di-oxide. In this compound the valency of carbon is $2 \times 2 = 4$. Similarly in barium oxide, (BaO), the valency of barium is $1 \times 2 = 2$. In aluminium oxide (Al_2O_3), two atoms of aluminium combine with three atoms of oxygen and so the valency of two aluminium atoms is $2 \times 3 = 6$. and so the valency of an aluminium atom is $6 \div 2 = 3$

So the valency of an element is the combining capacity of its atom and it is measured by the number of hydrogen atoms or the number of chlorine atoms or twice the number of oxygen atoms with which one atom of that element would combine.

The valency of elements is always a whole number because, according to Dalton's atomic theory, compounds are formed by the combination of atoms of elements in the ratio of small whole numbers.

Valency of Ions

You have studied ions are atoms or groups of atoms carrying positive or negative charges. Ions are formed by the

loss of or gain of electrons by atoms or groups of atoms. For example, an atom of sodium loses an electron and becomes sodium ion (Na^+). The sulphate (SO_4) radical gains two electrons and becomes sulphate ion (SO_4^{-2}). The valency of ions depend on the charge they possess. Sodium ion (Na^+) has one positive charge and its valency is one. Calcium ion (Ca^{++} or Ca^{+2}) has two positive charges and its valency is two. The valency of sulphate ion (SO_4^{-2}) is two and the valency of phosphate ion (PO_4^{-3}) is three.

From the examples given above, **the valency of an ion is equal to the number of positive or negative charges it possesses.**

Variable Valency

Some elements have more than one valency. For example, an atom of iron combines with two atoms of chlorine to form iron (II) chloride ($FeCl_2$). Here the valency of iron is two. An atom of iron combines with three atoms of chlorine to form iron (III) chloride ($FeCl_3$) and the valency of iron in this compound is three. Phosphorus combines with chlorine forming phosphorus (III) chloride (PCl_3) and phosphorus (V) chloride (PCl_5). The valency of phosphorus is 3 in PCl_3 and the valency of phosphorus in PCl_5 is 5. Copper (1, 2) Tin (2,4) and Arsenic (3, 5) are some more elements having variable valency. The valency of some elements and ions are given below :

VALENCY OF ELEMENTS

Valency 1		Valency 2		Valency 3	
Hydrogen	*H*	Oxygen	*O*	Nitrogen	*N*
Chlorine	*Cl*	Sulphur	*S*	Phosphorus	*P*
Bromine	*Br*	Magnesium	*Mg*	Aluminium	*Al*
Iodine	*I*	Calcium	*Ca*	Iron	*Fe*
Sodium	*Na*	Copper	*Cu*		
Potassium	*N*	Iron	*Fe*		
Silver	*Ag*	Tin	*Sn*		
Copper	*Cu*	Lead	*Pb*		
		Zinc	*Zn*		

Valency 4		Valency 5	Valency 6	
Carbon	C	Nitrogen N	Sulphur (in SO_3)	S
Silicon	Si	Phosphorus P		
Sulphur (in SO_2)	S			
Tin	Sn			
Lead	Pb			

VALENCY OF IONS

Valency 1		Valency 2		Valency 3	
Bicarbonate	HCO_3	Carbonate	CO_3	Phosphate	PO_4
Bisulphite	HSO_3	Sulphate	SO_4		
Bisulphate	HSO_4	Sulphite	SO_3		
Hydroxide	OH	Thiosulphate	S_2O_3		
Chlorate	ClO_3	Chromate	CrO_4		
Permanganate	MnO_4	Dichromate	Cr_2O_7		
Ammonium	NH_4	Manganate	MnO_4		
Chloride	Cl	Sulphide	S		
		Oxide	O		

If the valencies of elements, ions and radicals are known, the molecular formula of their compounds can be written easily.

Molecular Formula

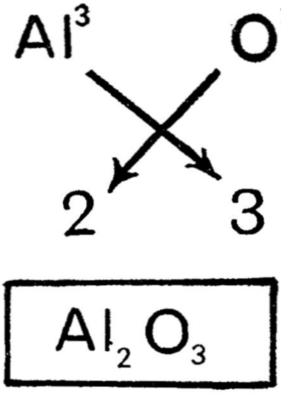
The molecular formula of a compound is the one showing the actual number of atoms of elements or ions present in it by means of symbols. The molecular formula is the symbolic representation of the one molecule of the substance. The molecular formula of water is H_2O. What does this mean ? One molecule of water contains two atoms of hydrogen and one atom of oxygen.

Writing the Molecular Formula

We shall see how we can write the formulae of compounds, if we know the elements and radicals present in their molecules and their valencies.

Example 1

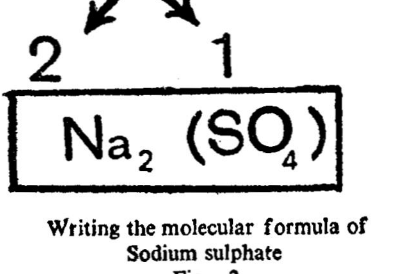
Let us see how to derive the molecular formula of aluminium oxide. We must write the symbol of aluminium (*Al*) and oxygen (*O*) side by side. The valency of aluminium is 3 and the valency of oxygen is 2. The respective valencies of the elements should then be written on top of the elements or radicals. The next step is to interchange the numbers and write the corresponding numbers at the bottom of the elements or radicals as shown in Fig. 2. In other words, the valency of aluminium which is 3 is written at the bottom of oxygen and the valency of oxygen which is 2 is written at the bottom of aluminium. Thus the molecular formula of aluminium oxide is obtained as Al_2O_3.



Method of writing the Molecular formula
Fig. 2

Example 2

The molecular formula of sodium sulphate can be found out in the same way. Sodium sulphate consists of two parts, sodium (*Na*) element and sulphate (SO_4) radical. The valency of sodium is 1 and the valency of sulphate radical is 2.



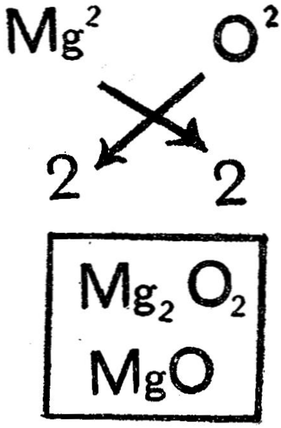
Writing the molecular formula of Sodium sulphate
Fig. 3

(a) First write the symbols of the element, sodium, and that of the radical, sulphate, side by side.

(b) Then write the valencies on the top of them as 1 and 2 respectively.

(c) Then interchange the valencies and write the numbers at their bottom.

(d) Now the molecular formula of sodium sulphate is obtained as Na_2SO_4



Writing the molecular formula of Magnesium oxide

Fig. 4

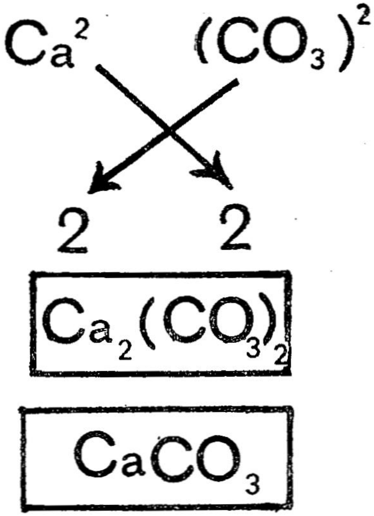
When the valencies of the elements of a compound are equal, then this process is not necessary and by writing their symbols side by side the molecular formula can be obtained.

Example 3

Let us find out the molecular formula of **magnesium oxide.** In this the valency of magnesium is 2 and that of oxygen is also 2. Since the values are equal, instead of writing the formula as Mg_2O_2 we can write the formula as MgO by dividing the valencies by the common factor 2.

Example 4

Calcium Carbonate



Writing the molecular formula Calcium carbonate

Fig. 5

The valency of calcium (Ca) is 2. The valency of carbonate redical is 2. The molecular formula of calcium carbonate is $CaCO_3$.

The molecular formula of some compounds are given below :

SUBSTANCE	METHOD	FORMULA
1. SODIUM CHLORIDE	Na^1 Cl^1 → 1, 1	$NaCl$
2. LEAD IODIDE	Pb^2 I^1 → 1, 2	PbI_2
3. CALCIUM PHOSPHATE	Ca^2 $(PO_4)^3$ → 3, 2	$Ca_3(PO_4)_2$
4. IRON (III) SULPHATE	Fe^3 $(SO_4)^2$ → 2, 3	$Fe_2(SO_4)_3$
5 ALUMINIUM CHLORIDE	Al^3 Cl^1 → 1, 3	$AlCl_3$

Molecular formula of compounds

Fig. 6

What do we learn from the Molecular Formula ?

1. The molecular formula shows the elements contained in it and also the symbols of elements.
2. It shows the ratio of elements contained in the compound., i.e., the actual number of atoms.
3. It shows the weights of elements contained in one molecule of the compound.
4. The molecular weight of the compound can be calculated.

Example

The molecular formula of sulphur-di-oxide is SO_2. From this we learn,

1. Sulphur-di-oxide contains sulphur and oxygen ; the symbol of sulphur is S and the symbol of oxygen is O.

2. One molecule of sulphur-di-oxide contains sulphur and oxygen in the ratio 1 : 2 by weight.

3. The atomic weight of sulphur is 32. The atomic weight of oxygen is 16. So the molecular weight of sulphur-di-oxide is $32 + (2 \times 16) = 64$.

Only when atoms of different elements really combine and form compounds, the molecular formula of such compounds can be written. But if elements do not combine, we should not guess that there are compounds containing such elements and write their molecular formula.

Questions

1. Define : Element, Compound.
2. Define : Atom, Molecule.
3. State the differences between atoms and molecules.
4. What is the valency of sulphur in sulphur -tri- oxide ?
5. Write down the molecular formula of the following :-
   (a) Calcium sulphate. (b) Magnesium phosphate.
   (c) Potassium nitrate. (d) Copper (II) carbonate.
6. Write down the valencies of the underlined elements or radicals in the following :-
   $\underline{Cu}\,Cl_2$, $\underline{P}H_3$, $\underline{Al_2}\,(SO_4)_3$, $\underline{Ba}\,O$, $Ca\,\underline{(NO_3)}_2$,
   $Ca_3\,\underline{(PO_4)}_2$, $Fe_2\,\underline{(SO_4)}_3$, $Ca\,\underline{CO_3}$
7. What is the importance of the molecular formula?
8. What do you know from the molecular formula H_2O?
9. Define the valency of an element.
10. What are ions?
11. How are the valencies of ions calculated?
12. Give examples of elements having variable valencies.
13. Calculate the molecular weight of sodium chloride. ($Na = 23$, $Cl = 35{\cdot}45$)

Know Yourself

1. The number of electrons gained or lost by an atom in order to attain the stable electronic structure of rare gases is its valency.

2. Helium, neon, argon, krypton and xenon are rare gases. Helium has two electrons in the outermost orbit, and the other elments have eight electrons in the outermost orbit. Hence they do not react with other elements.

3. In order to show the variable valency of an element the suffix 'ic' is used to show the higher valency and the suffix 'ous' is used to show the lower valency of the same element. Example : Ferrous chloride ($Fe\ Cl_2$) Ferric chloride ($Fe\ Cl_3$)

2. CHEMICAL EQUATIONS

Whenever new substances are formed by the combination or decomposition of elements and compounds, that change is called a chemical change. **Symbolic representation of such chemical changes in a short form is called chemical equation.**

Example

When carbon burns in air, it combines with oxygen and forms carbon-di-oxide. This reaction can be written as follows :

Carbon + Oxygen → Carbon-di-oxide

Instead of writing the names of elements and compounds, the symbols and molecular formula can be used to show the reaction :

$$C + O_2 \rightarrow CO_2$$

When limestone is heated strongly, it decomposes into calcium oxide (quick lime) and carbon-di-oxide. The molecular

formula of limestone is $Ca\,CO_3$. The molecular formula of quick lime is $Ca\,O$ and that of carbon-di-oxide is CO_2. The chemical equation for this reaction can be written as given below :

$$Ca\,CO_3 \rightarrow Ca\,O + CO_2$$

In this reaction the substance involved in the chemical change is calcium carbonate. This is called the "**reactants**". The substances formed as a result of the chemical change are calcium oxide and carbon-di-oxide and they are called the "**products**". Hydrogen combines with oxygen to form water.

$$2\,H_2 + O_2 \rightarrow 2\,H_2O$$

In this chemical reaction, hydrogen and oxygen are the reactants and water is the product.

In a chemical equation, the molecular formula of the reactants are shown on the left side and the molecular formula of the products are shown on the right side. An arrow (→) is put in between them. The arrow means "gives" or "forms".

A chemical equation is a symbolic representation of the initial and the final stages of a chemical reaction, showing in symbols and formula, the substances that react and the substances that are produced in appropriate quantities.

Method of writing the Equation

In order to write the chemical equation correctly, you must know the following :

1. Make sure whether the reaction really takes place. **Only for real reactions, equation must be written.**

2. The name and the molecular formula of the reactants and the products must be known.

On knowing the substances that react and the substances that are formed and their molecular formula, the equation must be written as follows :

1. Write the equation in words.

2. Using the symbols and formula of the reactants and the products, write down the unbalanced equation with an arrow (→) in between them.

3. In order to make the number of atoms of each element on either side of the equation to be equal, adjust the number of molecules of each of the substances by multiplying the formula by suitable numbers. This is called balancing the equation. Why should the equation be balanced?

Chemical equation is based on the **"Law of Conservation of Mass."** According to this, during a chemical change, the total mass of the reactants and the total mass of the products are equal. In a chemical change, atoms of a substance only change their positions. They are neither created nor destroyed.

4. If the products are gases, an upward arrow (↑) is put by their side. If the product is a precipitate, a downward arrow (↓) is put by its side.

Example 1

When water is electrolysed, water splits into hydrogen and oxygen. Hydrogen and oxygen are the products and both of them are gases. The reaction can be shown as below :

$$\text{Water} \xrightarrow{\text{Electrolysis}} \text{Hydrogen} \uparrow + \text{Oxygen} \uparrow.$$

The molecular formula of water is H_2O. The molecular formula of hydrogen and oxygen are H_2 and O_2 respectively. So the reaction can be written as :

$$\boxed{H_2O \longrightarrow H_2 \uparrow + O_2 \uparrow}$$

This is an unbalanced equation because the number of hydrogen atoms are equal on either side but the number of oxygen atoms are not equal. By putting 2 before H_2O, the number of oxygen atoms on either side will become equal. But the number of hydrogen atoms will not be equal.

$$2H_2O \rightarrow H_2\uparrow + O_2\uparrow$$

In order to make the number of hydrogen atoms equal on either side, the number 2 is put before H_2.

$$2H_2O \rightarrow 2H_2\uparrow + O_2\uparrow$$

In this equation, there are four hydrogen atoms and two oxygen atoms on either side. This is called a **balanced equation**. The number of atoms of each element on either side is equal. This is in agreement with the **Law of Conservation of Mass.**

Example 2

When potassium chlorate is heated, potassium chloride and oxygen are formed.

$$KClO_3 \rightarrow KCl + O_2\uparrow$$

In this equation the atoms of potassium and chlorine are balanced. But there are 3 oxygen atoms on the left side and there are only 2 oxygen atoms on the right side. In order to balance the oxygen atoms on either side, the equation can be written as follows :

$$KClO_3 \rightarrow KCl + 1\tfrac{1}{2}\,O_2\uparrow$$

In order to convert $1\frac{1}{2}\,O_2$ into the nearest whole number the equation is multiplied both sides by 2 and in order to show that the reaction is carried out only on heating Δ-sign is put above the arrow mark.

$$2KClO_3 \xrightarrow{\Delta} 2KCl + 3O_2\uparrow$$

Now the equation is balanced.

Example 3

When mercury (II) oxide is heated, it decomposes into mercury and oxygen.

$$HgO \xrightarrow{\Delta} Hg + O_2 \uparrow$$

First balance the oxygen atoms.

$$2\ HgO \xrightarrow{\Delta} Hg + O_2 \uparrow$$

Then balance the atoms of mercury.

$$2\ HgO \xrightarrow{\Delta} 2\ Hg + O_2 \uparrow$$

Since oxygen is a gas, an upward arrow is put by the side of oxygen. To show that the reaction takes place due to heating, a Δ-sign is put above the arrow, as shown in the equation.

What does a chemical equation tell us?

A chemical equation tells us :

(1) Information about the reactants and the products of the reaction.

(2) The molecular formula of the reactants and of the products.

(3) The molecular proportions of the reactants and of the products.

$$H_2 + Cl_2 \rightarrow 2\ HCl \uparrow$$

From this equation, we know that one molecule of hydrogen and one molecule of chlorine react to form two molecules of hydrogen chloride.

(4) From a chemical equation, the proportional weights of the reactants and of the products are known.

(5) It has a quantitative significance. The relative volumes of gases, if any, formed in the reaction can also be known.

Hence a balanced chemical equation has a qualitative and a quantitative significance as well.

$$C + O_2 \rightarrow CO_2$$

From this equation we learn,

(1) Carbon reacts with oxygen forming carbon-di-oxide.

(2) The symbol of carbon is C. The molecular formula of oxygen is O_3 and that of carbon-di-oxide is CO_2.

(3) The atomic weight of carbon is 12. The molecular weight of oxygen is $2 \times 16 = 32$. So 12 parts by weight of carbon combines with 32 parts by weight of oxygen and gives $12] + 32 = 44$ parts by weight of carbon-di-oxide. In other words, carbon and oxygen combine in the ratio $12 : 32 = 3 : 8$ by weight.

Limitations of a Chemical Equation

Though a balanced chemical equation conveys important information, it does not give a complete picture of the reaction.

(1) The equation does not tell us the conditions like temperature, pressure, catalyst etc. for the reaction to take place.

(2) It does not tell us whether the reactants are solids, liquids or gases.

(3) It does not tell us whether the reaction takes place on heating or on cooling and whether heat is evolved or absorbed during the reaction.

(4) It does not also indicate the time taken for the completion of the reaction.

(5) It does not also tell us whether the reaction is reversible or not.

In order to rectify some of the defects of chemical equations, the following methods are adopted :

(1) If the products are gases, an upward arrow $\uparrow$ is put by its side.

$$C + O_2 \rightarrow CO_2 \uparrow$$

(2) If a precipitate (undissolved substance) is formed during the reaction, a downward arrow ↓ is put by its side.

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu\downarrow$$

(3) If the reaction takes place only when heated, a, triangle Δ its put above the arrow.

$$C + O_2 \xrightarrow{\Delta} CO_2\uparrow$$

(4) To show whether the substances are solids, liquids or gases they are shown as below :

$$\underset{(s)}{C} + \underset{(g)}{O_2} \xrightarrow{\Delta} \underset{(g)}{CO_2}\uparrow$$

$$\underset{(s)}{Zn} + \underset{(l)}{CuSO_4} \rightarrow \underset{(l)}{ZnSO_4} + \underset{(s)}{Cu}\downarrow$$

The symbol (s) stands for solids, the symbol (g) stands for a gas and the symbol (l) stands for a liquid.

$$\underset{(s)}{C} + \underset{(g)}{O_2} \longrightarrow \underset{(g)}{CO_2}\uparrow + 394\ KJ$$

$$2\underset{(s)}{C} + 2\underset{(g)}{H_2} \longrightarrow \underset{(g)}{C_2H_4}\uparrow - 52\ KJ$$

In the above two equations, the states of the reactants and the products are shown and also whether heat is evolved or absorbed during the reaction is shown

Stoichiometric Calculations

This means calculations involving the weights and volumes of the reactants and the products. Balanced chemical equation helps us to make these calculations.

Problem 1

Calculate the weight of carbon-di-oxide formed when 10 gms. of calcium carbonate is heated.

Solution

Calcium carbonate, on heating, gives calcium oxide and carbon-di-oxide.

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2 \uparrow$$

The molecular weight of calcium carbonate

$$\begin{array}{llll} Ca & C & O_3 & CaCO_3 \\ 40 + 12 + (3 \times 16) = 100 \end{array}$$

The molecular weight of carbon-di-oxide.

$$\begin{array}{lll} C & O_2 & = CO_2 \\ 12 + (2 \times 16) = 44. \end{array}$$

According to the equation, 100 gms. of calcium carbonate on heating gives 44 gms. of carbon-di-oxide.

Weight of carbon-di-oxide formed when 10 gms. of carbonate is heated

$$\frac{44}{100} \times 10 = 4{\cdot}4 \text{ gms.}$$

Problem 2

Calculate the weight of potassium chlorate required to produce 20 gms. of oxygen.

The balanced equation for this reaction is

$$2\,KClO_3 \rightarrow 2\,KCl + 3\,O_2 \uparrow$$

$$2\,[39 + 35{\cdot}5 + (3 \times 16)] \rightarrow (6 \times 16) \text{ gms.}$$

$$245 \text{ gms} \rightarrow 96 \text{ gms.}$$

To produce 96 gms. of oxygen, weight of potassium chlorate required is 245 gms.

Weight of potassium chlorate required to produce 20 gms. of

$$\text{oxygen} = \frac{245}{96} \times 20 = 51{\cdot}04 \text{ gms.}$$

Questions

1. What is a chemical change ?
2. Define the terms : Reactants and Products.
3. What is a chemical equation ?
4. What do the following symbols represent in a chemical equation ? $\rightarrow$, Δ, $\downarrow$, $\uparrow$.
5. How is the law of conservation of mass useful to balance a chemical equation ?
6. What is a balanced chemical equation ?
7. What do you understand from a chemical equation ?
8. $2H_2 + O_2 \rightarrow 2H_2O$. What do you learn from this ?
9. What are the limitations of a chemical equation ?
10. Balance the following equations :

    (a) $KNO_3 \rightarrow KNO_2 + O_2$
    (b) $HNO_3 \rightarrow H_2O + NO_2 + O_2$
    (c) $H_2 + Cl_2 \rightarrow HCl$
    (d) $P + O_2 \rightarrow P_2O_5$
    (e) $P + Cl_2 \rightarrow PCl_3$
    (f) $Cu(NO_3)_2 \rightarrow CuO + NO_2 + O_2$
    (g) $Fe + HCl \rightarrow FeCl_2 + H_2$
    (h) $Cu + AgNO_3 \rightarrow Cu(NO_3)_2 + Ag$

11. Give the chemical equations for the following :
    (a) Magnesium burns in oxygen.
    (b) Hydrogen burns in oxygen.
    (c) Calcium carbonate is heated.
    (d) Hydrogen and sulphur combine to form hydrogen sulphide.
12. Calculate the weight of sulphur-di-oxide formed when 1 gm. of sulphur is burnt completely.
13. Calculate the weight of oxygen obtained when 2·44 gms. of potassium chlorate is heated.
14. Calculate the weights of hydrogen and oxygen required to produce 72 gms. of water.

3. LAWS OF CHEMICAL COMBINATION

Substances in all states (solid, liquid, or gaseous) react with each other. Elements combine to form compounds. The formation of compounds from elements and the conversion of one compound into another are based on certain experimental facts. Based on these facts, many laws have been deduced. They are known as **laws of chemical combinations.**

During chemical reactions, in what ratio by weight do the reacting substances combine? Will there be a change in the weight of the reactants that undergo chemical change? The laws of chemical combinations provide answers to these questions and explain the basic principles involved in chemical reactions. The laws of chemical combinations are :

(*a*) Law of Conservation of Mass

(*b*) Law of Definite or Constant Proportions

(*c*) Law of Multiple Proportions

(*d*) Law of Reciprocal Proportions

(*e*) Law of Combining Volumes

The first four laws are based on the weights of substances. The fifth law is concerned with the volume of combining substances when they are gases. Let us know about the first three laws.

Lavoisier
Fig. 6 (a)

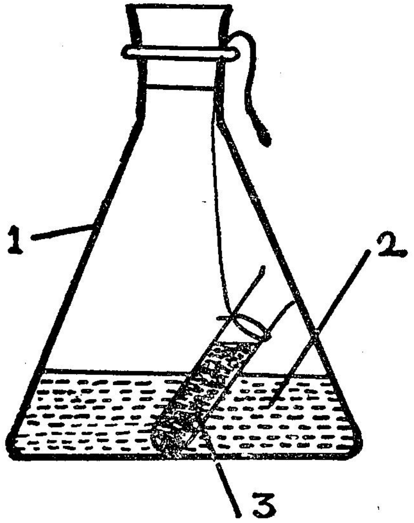
(*a*) Law of Conservation of Mass

In a chemical change, the total mass of the products is equal to the total mass of the reactants.

It was **Lavoisier** who put forward this law in 1789. According to this law, during a chemical change, mass is neither created nor destroyed. Elements change their places and form the products. But the total mass of the products will remain equal to the total mass of the reactants.

Experiment

Take 50 ml. of dilute lead nitrate solution in a 250 ml. capacity conical flask. In a small test tube, take potassium,



1. Conical flask 2. Lead nitrate solution
3. Potassium iodide solution

Fig. 6 (b)

iodide solution. Suspend this test tube in the flask by means of a thread. Close the mouth of the flask by means of a rubber stopper or cork so that the two solutions do not mix. Now find the weight of the flask accurately.

Then tilt the flask slightly and make the two solutions mix with each other. Note that lead nitrate will react with potassium iodide forming yellow precipitate of lead iodide. The formation of yellow precipitate shows that chemical reaction has taken place.

$$Pb(NO_3)_2 + 2\,KI \longrightarrow PbI_2 \downarrow + 2\,KNO_3$$

Now find the weight of the flask accurately with the contents. Note that the weights of the flask with contents before the reaction and after the reaction are equal.

Repeat this experiment changing the volumes of lead nitrate and potassium iodide. In each case, the weight of the flask before the reaction and after the reaction will be equal.

Hence, in a chemical change, the total mass of the products is equal to the total mass of the reactants.

Note

Do the above experiment using silver nitrate solution and sodium chloride solution.

$$AgNO_3 + NaCl \longrightarrow AgCl \downarrow + NaNO_3$$

(*b*) **Law of Definite Proportions**

This law was discovered by **L. Proust** in 1979. **J. S. Stass and T. W. Richard** verified the law by means of experiments. **The law of definite proportions** can be stated as follows :

'The same compound, by whatever method it is prepared, always contains the same elements combined in a fixed proportion by weight.'

From this, you can know that the chemical composition of a compound does not depend on the method of preparation and the ratio of weights of the elements present in a compound is always a constant.

A chemical compound can be prepared by various methods. for example : Copper (II) oxide can be prepared by the following methods :

1. When copper carbonate is heated, it gets converted into copper (II) oxide.

$$CuCO_3 \xrightarrow{\Delta} CuO + CO_2 \uparrow$$

2. Copper (II) hydroxide on heating gives copper (II) xide.

$$Cu(OH)_2 \xrightarrow{\Delta} CuO + H_2O \uparrow$$

3. When copper (II) nitrate is heated, it decomposes and gets converted into copper (II) oxide.

$$2\,Cu(NO_3)_2 \xrightarrow{\Delta} 2\,CuO + 4\,NO_2 + O_2\uparrow$$

The copper (II) oxide prepared by the different methods contains copper and oxygen in the ratio 4 : 1.

Illustration - Problem

In an experiment, 1·76 gms. of copper heated with con. nitric acid gave 2·20 gms. of copper oxide. In another experiment when hydrogen was passed over 1·15 gms. of copper (II) oxide gave 0·92 gm. of copper. How will you prove that this explains the Law of Definite Proportions ?

Solution : Experiment No. 1

Weight of copper (II) oxide = 2·20 gms.

Weight of copper = 1·76 gms.

∴ Weight of oxygen = 0·44 gm.

Weight of oxygen that combines with 1·76 gm. of copper = 0·44 gm.

∴ Weight of copper that combines with one gram of oxygen $= \frac{1·76}{0·44} = 4$ gms.

∴ Ratio of copper : oxygen = 4 : 1.

Experiment No. 2

Weight of copper (II) oxide = 1·15 gms.

Weight of copper = 0·92 gm.

∴ Weight of oxygen = 0·23 gm.

∴ Weight of oxygen that combines with 0·92 gm. of copper = 0·23 gm.

∴ Weight of copper that combines with one gram of oxygen $= \frac{0·92}{0·23} = 4$ gms.

∴ Ratio of copper : oxygen = 4 : 1.

The copper (II) oxide used in these two experiments contain copper and oxygen in the same ratio by weight. These data illustrate the law of definite proportions.

(c) Law of Multiple Proportions

Two different elements may sometimes combine to form more than one compound. For example, the elements hydrogen and oxygen combine to form water and hydrogen peroxide. The compounds and the ratio of the elements by weights with which they combine are given below :

Compound	Weight of Hydrogen (gm)	Weight of Oxygen (gm)
Water (H_2O)	1·008	8
Hydrogen peroxide (H_2O_2)	1·008	16

The different weights of oxygen that combine with the same fixed weight of 1·008 gms. are 8 gms. and 16 gms. In these two compounds, the ratio of the different weights of oxygen that combine with the fixed weight of hydrogen is 8 : 16 or 1 : 2. This is simple integral ratio. Similarly nitrogen and oxygen combine to form four different oxides. The compositions are given below :

Compound	Weight of Nitrogen (gm)	Weight of Oxygen (gm)
Nitrous Oxide	14	8
Nitric Oxide	14	16
Nitrogen (II) Oxide	14	32
Nitrogen (V) Oxide	14	40

Here the different weights of oxygen that combine with the fixed weight of 14 gms. of nitrogen are 8 gms. 16 gms., 32 gms. and 40 gms. The ratio of the weights of oxygen that combine with

the fixed weight of 14 gms. of nitrogen is 8 : 16 : 32 : 40 or 1 : 2 : 4 : 5. This is also a simple integral whole number. **John Dalton** in 1803 put forward this fact in the form of a law.

"If two elements combine together to form more than one compound, the different weights of one of the elements that combine with the fixed weight of the other will be in the ratio of small whole numbers". This is called the Law of Multiple Proportions.

John Dalton
Fig. 6 (c)

Illustration-Problem

Two different oxides of a metal weighing 0·429 gm. and 0·450 gm. on reduction gave 0·381 gm. and 0·359 gm. of the metal respectively. Show that these results prove the law of multiple proportions.

First Oxide

Weight of metallic oxide = 0·429 gm.

Weight of metal = 0·381 gm.

∴ Weight of oxygen that combines with 0·381 gm. of metal = 0·048 gm.

,, Weight of oxygen that combines with one gram of metal $= \frac{0{\cdot}048}{0{\cdot}381} = 0{\cdot}126$ gm.

Second Oxide

Weight of metallic oxide = 0·450 gm.

Weight of metal = 0·359 gm.

∴ Weight of oxygen that combines with 0·359 gm. of metal = 0·091 gm.

,, Weight of oxygen that combines with one gm. of metal $= \frac{0{\cdot}091}{0{\cdot}359 \text{ gm.}} = 0{\cdot}252$ gm.

Therefore the ratio of the weights of oxygen that combines with one gram of the metal is 0·126 : 0·252 = 1 : 2.

This is a simple integral ratio. This explains the law of multiple proportions.

Questions

1. What are the laws of chemical combinations?

2. State the law of conservation of mass.

3. State the law of multiple proportions.

4. Describe the experiment to prove the law of conservation of mass.

5. Mention the precipitate formed when lead nitrate reacts with potassium iodide.

6. What is the precipitate formed when sodium chloride reacts with silver nitrate?

7. Give the names of the scientists who first discovered the law of conservation of mass, the law of multiple proportions and the law of definite proportions.

8. What happens when hydrogen is passed over heated copper (II) oxide. Give the equation.

9. State the law of definite proportions.

10. 0·8 gm. of copper oxide on reduction gave 0·64 gm. of copper. One gram of copper on oxidation gave 1·25 gms. of copper oxide. Show that this illustrates the law of definite proportions.

Know Yourself

Water, by whatever method it is prepared, always contains hydrogen and oxygen in the ratio 1 : 8 by weight.

4. KINETIC THEORY OF GASES

Substances exist in three states namely solids, liquids and gases. All of them are composed of minute particles known as molecules.

Solid State

In solids, the molecules are very closely packed and they remain in their places. Hence solids have definite shape and volume.

Liquid State

In liquids, the molecules are closely packed but not to the extent as in solids. They are capable of moving from one place to another. Liquids have definite volume but they do not have definite shape. They take the shape of the containing vessel.

Gaseous State

Gases are composed of molecules. But these molecules are not closely packed and they are far apart and they are capable of moving easily from one place to another. Gases do not have definite volume and definite shape. Liquids and gases are known as fluids since they flow from one vessel to another or one place to another. Gases spread and occupy the entire space of the container. It spreads freely and its volume decreases to a large extent by the application of pressure. Why? How do gases exert pressure? What are the evidences to show that gases diffuse? For these questions, we can find the answer from the following experiments :

Experiments to show Gas Molecules are in Motion :

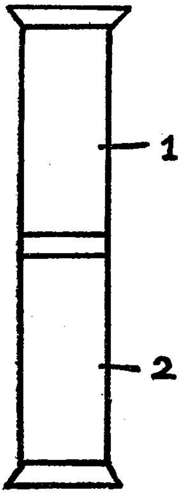
Spreading of Smell

Keep open a bottle containing alcohol and feel its smell. Keep the bottle open at some distance and see whether you are able to feel any smell. You will feel the smell of alcohol. What is the reason for this? When motor cars are filled with petrol. and if some petrol is spilt, it evoporates and we feel the smell of petrol. In the laboratary, if we open the bottle

containing ammonia solution and smell it, we feel the irritating smell of ammonia. How are we to account for these experiences?

Substances mentioned above (alcohol, petrol and ammonia) consist of small particles called molecules. When the bottle containing alcohol is opened, alcohol evaporates and the molecules are not visible. Yet we can feel the smell of alcohol even at a distance. The reason for this is the molecules of alcohol mix with air and reach our nose. This shows that the invisible molecules move. In the same way, ammonia and petrol evaporate and the molecules that mix with air reach our nose and we feel their smell. You can now know the reason why we are able to feel the smell of foodstuffs while they are being cooked in our kitchen.

Volume of Molecules



1· Air
2. Hydrogen
Fig. 7

Molecules are very very small and they cannot be seen even with a powerful microscope. But scientists say that the existence of such molecules of a gas can be known with the help of electron microscopes. A drop of water contains approximately, 13×10^{10} molecules. This shows how small the molecules are.

Mass of Molecules

The molecules are very very small and so the mass of the molecules will be very very small. The molecules of different substances like oxygen, carbon-di-oxide and chlorine have different masses. This can be understood by some experiments.

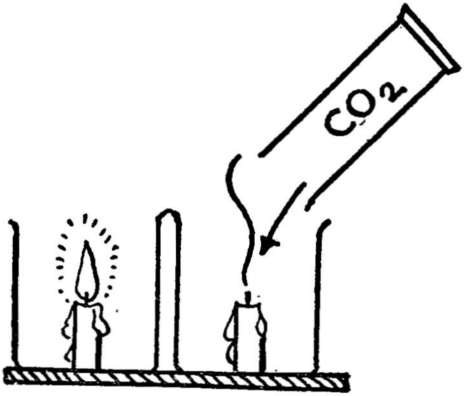
Experiment 1

Invert a jar containing air over a jar containing hydrogen. Remove the lid of the jar containing hydrogen. After sometime introduce a burning splinter in the jar which contains air. The gas burns with a "pop" sound. This is the property of

hydrogen. Introduce another burning splinter into the jar which contained hydrogen. No change will be observed. What do you infer from this ? Hydrogen, which was in the lower jar, has gone into the upper jar which contained air and the air in the upper jar has come into the lower jar which contained hydrogen. This shows that hydrogen molecules are lighter than air.

Experiment 2

Place a burning candle in a beaker. Invert a gas jar containing carbon-di-oxide in a slanting position over the



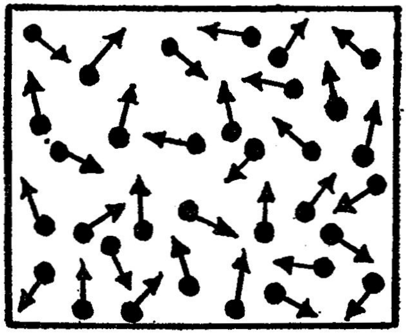
Pouring Carbon-di-oxide

Fig. 8

beaker. After some time, it is observed that the candle is put out. The reason for this is the heavier carbon-di-oxide has gone down into the beaker which contained air and it prevented the flame getting into contact with air. This experiment indicates that the mass of carbon-di-oxide molecules is greater than the mass of the air molecules.

From these two experiments, we learn that molecules are in motion and hydrogen is lighter than air and carbon-di-oxide is heavier than air. The motion of the molecules can be well understood by observing a common phenomenon in every day life.

You might have seen a beam of sunlight entering your room through the small openings or holes on the roof. You



Movement of Molecules

Fig. 9

might have seen certain particles moving here and there in a zig zag fashion continuously. The particles that move are dust particles. Air contains a number of moleclues invisible to the eye and these molecules are in motion in all directions. During their movement, they collide with the dust particles. As a result, the dust particles move in an irregular manner. What do you infer from this? The molecules of substances are in random, continuous motion in all directions.

Experiment 3

Take a gas jar. Put a few drops of bromine liquid and close the mouth of the jar by a glass lid. Observe what happens.

Bromine in the jar evaporates and bromine vapour spreads little by little and occupies the entire jar. From this, we conclude that the molecules of bromine vapour are in motion and penetrate into air and mix with it. The property of the intermixing of the gaseous molecules is known as diffusion.

If the molecules of air are very close to each other without much space between them, it is not possible for the

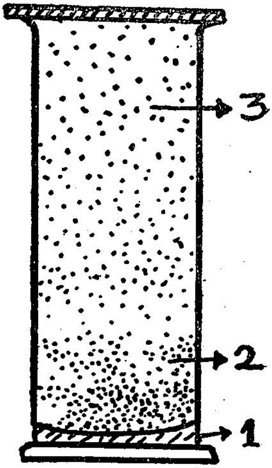
molecules of bromine vapour to spread and diffuse between the air molecules. This experiment shows that there is much space between the molecules of a gas.

Pressure of Gases

Gases exert pressure in all directions. The reason for this can be shown by an experiment.

Experiment

Take a rubber bladder of a foot-ball and pump in some air by means of an air-pump. Press it. You may be able to press the bladder a little. Now pump in more air with the pump and try to press the bladder. Now you require greater force to press it. You may also note that when you try to press the bladder, your hand is pushed back and the hand experiences an opposite force exerted on it.



Diffusion of Bromine

1. Liquid Bromine
2. Dense vapour of Bromine
3. Rarer vapour of Bromine

Fig. 10

As you send in more and more air into the rubber bladder, the pressure of air increases. The air molecules strike the inner wall of the bladder and push it outward. When we try to press the bladder from outside, it does not get compressed because of the high pressure of air inside.

You learnt that the molecules of air move continuously in a zig zag manner. The molecules of air inside the rubber bladder move and collide with the walls of the bladder. Because the molecules strike against the walls of the bladder, they cause impacts on the wall. These impacts of the molecules on the walls of the bladder give rise to the pressure of air. When you send in more and more air into the bladder, the number of molecules of air increases. Hence, the number of impacts on the walls increases and the pressure increases. **The pressure of a gas is due to the collision of the molecules of the gas against the walls of the container.**

Elasticity of Collision

When a rubber ball is thrown against a wall from a distance, the ball hits the wall and rebounds with the same velocity. You might have experienced this. After its impact on the wall, it does not lose its kinetic energy and so the ball rebounds in the opposite direction with the same velocity. This property is called elasticity.

If a stone is thrown against wall, the stone will hit the wall, but it will not come back; instead it will fall down. Why?

When the stone hits on the wall, it loses its kinetic energy as a result of the impact. Just like the rubber ball, the molecules of a gas are perfectly elastic. That is why the molecules of a gas in a vessel even after a number of collisions against the walls of the vessel do not lose their kinetic energy. Hence, they are in continuous motion and molecular collisions are perfectly elastic. As a result, the average kinetic energy of the gaseous molecules remains almost constant at a particular temperature.

Temperature and the Kinetic Energy of Gas Molecules

When a bicycle is kept in the hot sun, you might have seen that sometimes the rubber tube containing air in the bicycle bursts with an explosive sound. What is it due to? The temperature of air inside the rubber tube increases due to the heat of the sun and the kinetic energy of molecules of air inside the tube also increases. As a result, the number of collisions of the molecules of air against the inner walls of the tube also increases. Hence, the pressure increases and the tube bursts.

In the same manner, if a balloon filled with air is held near a flame, without touching the flame, the balloon bursts. Why?

The temperature of the air inside the balloon increases resulting in the increase of the kinetic energy of the molecules of the air. Because of this, the number of collisions increases.

The pressure of air inside the balloon increases and the balloon bursts.

From these experiments, we conclude that the kinetic energy of the molecules of a gas is directly proportional to the temperature.

Kinetic Theory of Gases

From the results of the experiments on gases, described above, a theory was developed. It is known as kinetic theory of gases. This was first published by **James Clerk Maxwell** in 1860.

The basic postulates of the kinetic theory of gases can be stated as follows :

1. All gases consist of very minute particles called molecules.

2. Gas molecules move, rapidly in all directions continuously in an irregular and zig zag manner.

3. When the molecules move, they collide with each other and also against the walls of the container.

4. Gas molecules are perfectly elastic. Their collisions are perfectly elastic and so they do not lose any energy due to collision.

5. The pressure of a gas is the result of the collision of the gas molecules on the walls of the container.

6. The kinetic energy of the gas molecules is directly proportional to the temperature.

7. There is no intermolecular attraction between the gas molecules. So the molecules are able to move freely.

8. The volume of a molecule is very small compared to the volume of the container. Hence it can be neglected.

Questions

1. How do we get the smell of alcohol from an open bottle containing alcohol ?

2. Are the masses of the molecules of all substances the same?

3. How will you show that the molecules of different substances have different masses?
4. What do you conclude from the diffusion of bromine vapour?
5. How does a gas exert pressure?
6. What are the factors on which the pressure of a gas depend?
7. What do you know of the collisions of gas molecules? What is its result?
8. Why does the volume of a gas increase with increase in temperature?
9. State the postulates of the kinetic theory of gases.
10. What will happen if a balloon containing air is kept to in the hot sun? Why?

Know Yourself

When the temperature of a gas increases, the kinetic energy of the gaseous molecules increases and the space between the molecule increases. So the volume of the gas increases.

5. AVOGADRO'S HYPOTHESIS

Law of Combining Volumes

There are reactions in which gases react to produce gaseous products. For example, hydrogen combines with chlorine forming hydrogen chloride gas.

$$H_2 + Cl_2 \longrightarrow 2\,HCl$$

One volume of hydrogen combines with one volume of chlorine to produce two volumes of hydrogen chloride. If all the three gases are at the same temperature and pressure, the ratio of the volumes $H_2 : Cl_2 : HCl$ will be in the ratio 1 : 1 : 2.

Hydrogen reacts with nitrogen forming ammonia.

$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

Here one volume of nitrogen reacts with three volumes of hydrogen to produce two volumes of ammonia. Here the ratio of the reacting gases and the products $N_2 : H_2 : NH_3$ will be in the ratio 2 : 3 : 2 by volume.

From these examples, when gases react forming gaseous products, we conclude that ratio of the reacting gases and the gaseous products are in small whole numbers by volume.

This fact was enunciated by Gay Lussac in 1804 in the form of a law. It is called Gay Lussac's law of gaseous volumes. It is applicable only for the non-reacting gases. The law can be stated as follows:

"Whenever gases combine to give gaseous products, the volumes of reacting gases and that of the products formed are in ratio of small whole numbers provided these volumes are measured under the same conditions of temperature and pressure".

According to Dalton's Atomic Theory, **atoms combine in the ratio of small whole numbers.** Gay Lussac's law states that **the ratio of the volumes of the reacting gases and the volumes of the gases produced will be in the ratio of small whole numbers.** From these two laws it is inferred that there exists some relationship between the volumes of gases and the number of atoms present in them.

Based upon this, **Berzelius** put forward a hypothesis known as Berzelius hypothesis which states that, **"equal volumes of all gases under the same conditions of temperature and pressure contain equal number of atoms".**

If this hypothesis is applied to the reaction of hydrogen and chlorine forming hydrogen chloride, it leads to contradiction.

One volume of hydrogen reacts with one volume of chlorine forming two volumes of hydrogen chloride.

According to Berzelius hypothesis, let us assume that one volume of the gas contains '*n*' atoms. Then,

'n' hydrogen atoms + 'n' chlorine atoms. → 2 'n' hydrogen chloride compound atoms. Removing 'n' from both sides, one hydrogen atom + one chlorine atom → 2 hydrogen chloride compound atoms. Therefore to produce one hydrogen chloride molecule, ½ an atom of hydrogen and ½ an atom of chlorine are required. This is in conflict with Daltons's atomic theory that atoms combine in the ratio of small whole numbers. Again according to atomic theory, atoms are indivisible. Hence Berzelius hypothesis was not to be accepted.

In 1811, an Italian scientist called **Avogadro** stated that, " substances are made of particles called molecules. Molecules are composed of atoms. When chemical reactions take place, molecules first split into atoms and then react. Molecules have free existence. But atoms do not have independent existence. Based on this, he introduced a hypothesis known as Avogadro's hypothesis which states **"Equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules".** Let us apply this hypothesis to the formation of hydrogen chloride.

Avogadro (1776-1856)
Fig. 11

(one volume of hydrogen) + (one volume of chlorine) → (two volumes of hydrogen chloride)

Let us assume that one volume of the gas contains 'n' molecules ("n" molecules of hydrogen) + ('n' molecules of chlorine)→ *2* 'n' molecules of hydrogen chloride)

Therefore

one molecule of hydrogen	+	one molecule of chlorine	→	Two molecules of hydrogen chloride

One hydrogen chloride molecule must contain at least one hydrogen atom and one chlorine atom. So two hydrogen

chloride molecules must contain two hydrogen atoms and two chlorine atoms. Thus there must be two hydrogen atoms in one molecule of hydrogen. Similarly there must be two chlorine atoms in one molecule of chlorine. The reaction can be written as given below :—

$$\boxed{H \mid H} + \boxed{Cl \mid Cl} \rightarrow \boxed{HCl} + \boxed{HCl}$$

Moreover, in the case of gaseous reactions one molecule represents one volume. In the above example, one molecule of hydrogen combines with one molecule of chlorine producing two molecules of hydrogen chloride. So the ratio of these volumes is 1:1:2. This is in agreement with Gay Lussac's law of gaseous volumes.

Finding the Atomicity of Elementary Molecules

Atoms combine to form molecules and so molecules must be composed of atoms.

The number of atoms in a single molecule of an element is called its atomicity.

The atomicity of elementary gases like hydrogen, oxygen and chlorine can be determined by using Avogadro's hypothesis. Knowing the atomicity of the element, the molecular formula of the element can be written.

Atomicity of Hydrogen and its Molecular Formula

One volume of hydrogen combines with one volume of chlorine to form two volumes of hydrogen chloride. (i.e.)

(one volume of hydrogen) + (one volume of chlorine) → two volumes of hydrogen chloride)

Let us assume that one volume of the gas contains '*n*' molecules. According to Avogadro's hypothesis.

('*n*' molecules of hydrogen) + ('*n*' molecules of chlorine) → ('2, *n*' molecules of hydrogen chloride)

(one molecule of hydrogen) + (one molecule of chlorine) → (two molecules of hydrogen chloride)

∴ (½ molecule of hydrogen) + (½ molecule of chlorine) → (one molecule of hydrogen chloride)

Atoms cannot be split. So one hydrogen chloride molecule must contain atleast one atom of hydrogen and this must have come from ½ a molecule of hydrogen and so there must be at least one atom of hydrogen in ½ a molecule of hydrogen and so one molecule of hydrogen must contain two atoms of hydrogen. Therefore the atomicity of hydrogen is 2. Hence the molecular formula of hydrogen is H_2. In the same way, it can be shown that the atomicity of chlorine is two and its molecular formula is Cl_2.

Important gaseous elements and their atomicity

Gas	Atomicity	Molecular formula
Hydrogen	2	H_2
Chlorine	2	Cl_2
Oxygen	2	O_2
Nitrogen	2	N_2
Neon	1	Ne
Ozone	3	O_3

Gram Molecular Weight

If the molecular weight is expressed in grams, it is known as gram molecular weight. The molecular formula of hydrogen is H_2 and its molecular weight is $1 \times 2 = 2$. The gram-molecular weight of hydrogen is 2 gms. The molecular formula of oxygen is O_2 and its molecular weight is $16 \times 2 = 32$. The gram molecular weight of oxygen is 32 gms. The molecular formula of nitrogen is N_2 and its gram-molecular weight is $2 \times 14 = 28$ gms.

One gram-molecular weight of all gases under the same conditions of temperature and pressure contain equal number of molecules. Its value is $6{\cdot}023 \times 10^{23}$. It is a constant and it is known as **Avogadro's Number.**

If we consider one gram-molecular weight of hydrogen or one gram-molecular weight of oxygen or one gram-molecular weight of any gas, they will have equal number of molecules and its value will be $6{\cdot}023 \times 10^{23}$

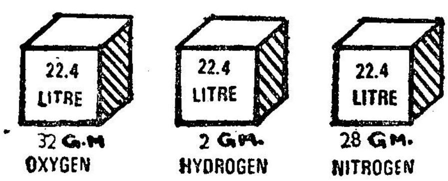
What do you infer from this?

At the same temperature and pressure, since gases contain equal number of molecules, what would be their volumes? Since at the same temperature and pressure, gases contain equal number of molecules, their volumes must necessarily be equal. Is this not the converse of Avogadro's hypothesis? This can be stated as follows :

"Under the same conditions of temperature and pressure, the volumes of all gases having equal number of molecules will be equal"

Molar Volume or Gram-Molar Volume

You have studied that one gram-molecule of any gas at standard temperature and pressure contains $6{\cdot}023 \times 10^{23}$ molecules. If we consider one gram molecule of different gases, they must contain equal number of molecules at standard temperature and pressure. Hence their volumes also must be equal. It has been discovered by experiments that **at standard temperature and pressure (S. T. P) one gram molecule of any gas has a volume of 22·4 litres. So at S.T.P., the volume of one gram molecule weight of any gas is 22·4 litres and this constant volume is called molar volume. This is true for all gases.**



Molar Volume
Fig. 12

In other words, 32 gms. of oxygen, 2 gms. of hydrogen or 28 gms. of nitrogen at standard temperature and pressure will have a volume of 22·4 litres.

The molecular weight of some gases and their molar volume at S.T.P. are given below :

Gas	Molecular formula	Gram molecular (gms) weight	Molar volume (litres)
Hydrogen	H_2	2	22·4
Oxygen	O_2	32	22·4
Nitrogen	N_2	28	22·4
Chlorine	Cl_2	71	22·4

From the table it is evident, the volume of one gram molecular weight of any gas at standard temperature and pressure is called gram-molecular volume or molar volume and it is always a constant.

Questions

(1) State Gay Lussac's Law of Gaseous Volumes.

(2) State Berzelius hypothesis.

(3) State Avogadro's hypothesis.

(4) State the converse of Avogadro's hypothesis.

(5) Define atomicity of an element.

(6) What is the atomicity of hydrogen, oxygen and chlorine?

(7) Derive the atomicity of hydrogen, using Avogadro's hypothesis.

(8) Define grammolecular weight ?

(9) Give the gram-molecular weight of oxygen and hydrogen.

(10) What is meant by S.T.P. ?

(11) What is the volume of 32 gms. of oxygen at S.T.P.

6. MOLECULAR WEIGHT

Atoms are the smallest particles invisible to our eyes. Millions of atoms can be placed at a pin point. In one gram of hydrogen, there are 600,000 million, million, million atoms. The weight of an atom of hydrogen which is the lightest element is $1{\cdot}7\times 10^{-24}$ gm. An atom of oxygen is 16 times heavier than the hydrogen atom and an atom of carbon is 12 times heavier than the hydrogen atom. So it is clear that there is no use of expressing the atomic weight or molecular weight in grams.

Hence the atomic weight of an element is compared with the atomic weight of hydrogen and the relative atomic weight is determined by having the weight of an atom of hydrogen as standard. For this purpose, the atomic weight of hydrogen is taken as one since it is the lightest of all elements.

Based on this, the atomic weight of an element can be defined as follows :

" The atomic weight of an element is the ratio of the weight of an atom of the element to the weight of an atom of hydrogen"

The atomic weight of an element is the number of times by which its atom is heavier than an atom of hydrogen. So it is expressed as a mere number.

$$\text{Atomic weight} = \frac{\text{weight of an atom of the element}}{\text{weight of an atom of hydrogen}}$$

In the same way, **the molecular weight of an element or a compound is defined as the ratio between the weight of one molecule of the element or the compound and the weight of one atom of hydrogen.**

$$\text{Molecular weight of a substance} = \frac{\text{weight of 1 molecule of the substance}}{\text{weight of 1 atom of hydrogen}}$$

Nowadays molecular weights and atomic weights are calculated on the basis of carbon-12 as standard.

So the atomic weight of an element is now defined as the number of times an atom of the element is heavier than 1/12th of

the weight of a carbon-12 atom. According to this carbon-12 standard,

$$\text{atomic weight of an element} = \frac{\text{weight of an atom of an element}}{\frac{1}{12} \times \text{weight of one carbon-12 atom}}$$

Similarly the molecular weight of an element or a compound is now defined as the number of times, its molecule is heavier than 1/12th of the weight of an atom of carbon-12.

$$\text{Molecular weight of a substance (element or compound)} = \frac{\text{weight of a molecule of an element}}{\frac{1}{12} \times \text{weight of 1 carbon-12 atom}}$$

Vapour Density

The density of solids and liquids is expressed as gm/ml. But since the densities of gases are very very small, they cannot be expressed in gms/ml. The density of a gas is compared with the density of hydrogen as the standard.

The ratio of the weight of a certain volume of the gas to the weight of the same volume of hydrogen at the same temperature and pressure is defined as the vapour density of the gas. The terms, vapour density and the relative density are one and the same.

$$\text{Vapour density of a gas} = \frac{\text{weight of a certain volume of the gas}}{\text{weight of the same volume of hydrogen at the same temparature and pressure}}$$

or

$$\text{Vapour density} = \frac{\text{weight of 1 litre of the gas}}{\text{weight of 1 litre of hydrogen at the same temperature and pressure}}$$

The relative density or vapour density of a gas is a ratio. It is expressed as a mere number and it has no units. It simply denotes how many times a certain gas is heavier than the weight of an equal volume of hydrogen.

Relation between Vapour Density and Molecular Weight

The relation between vapour density and molecular weight can be derived by using Avogadro's hypothesis.

$$\text{Vapour density of a gas} = \frac{\text{weight of a certain volume of the gas}}{\text{weight of the same volume of hydrogen at the same temparature and pressure}}$$

Let us assume that there are '*n*' molecules in a certain volume of the gas. According to Avogadro's hypothesis, the same volume of hydrogen at the same temperature and pressure should contain "*n*" molecules,

$$\therefore \text{Vapour density} = \frac{\text{weight of '}n\text{' molecules of the gas}}{\text{weight of '}n\text{' molecules of hydrogen}}$$

$$= \frac{\text{weight of 1 molecule of the gas}}{\text{w ight of 1 molecule of hydrogen}}$$

$$\text{Vapour density of the gas} = \frac{\text{weight of one molecule of the gas}}{\text{weight of one atom of hydrogen}}$$

One molecule of hydrogen contains 2 atoms of hydrogen.

$$\text{But molecular weight of the gas} = \frac{\text{weight of 1 molecule of the gas}}{2 \times \text{weight of one atom of hydrogen}}$$

$$\therefore \text{Vapour density} = \frac{\text{molecular weight of the gas}}{2}$$

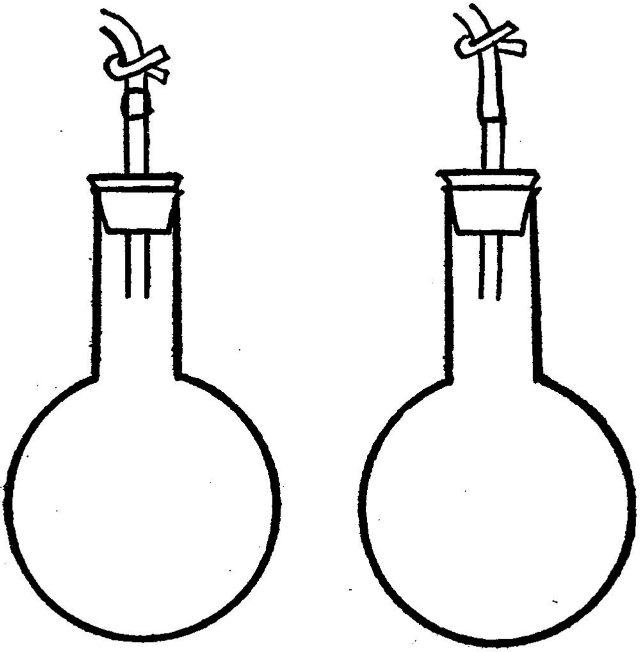
Therefore molecular weight of the gas $= 2 \times$ vapour density.

Determination of Molecular Weight

Experiment - Regnault's Method

Take two big flasks having exactly the same capacity and weight. Remove all the air from the two flasks by means of a vacuum pump. Suspend one flask from the hook of a chemical balance and the other from the other hook of the same balance. Now the beam of the balance will remain horizontal. Fill the flask suspended from the left hook with the gas at known temperature and pressure whose vapour density is to be known. There will be an increase in weight of the flask. This is due to the weight of the gas. The weight of the gas filled in the flask can be found accurately by placing weights in the right pan (from which the other flask is suspended). Note the increase in weight. Let it be X gm. This is the weight of the gas.

Then remove the gas completely from the flask and fill the flask with hydrogen at the same temperature and pressure



Regnault's Method–Determining Vapour Density
Fig. 13

and note the increase in weight as before. This is the weight of hydrogen. Let it be y gm.

In this experiment, since the flasks are identical, the weights of same equal volumes of the gas and hydrogen at the same temperature and pressure are determined.

$$\text{Hence vapour density of the gas} = \frac{\text{weight of the gas in the flask}}{\text{weight of hydrogen in the flask.}}$$

Calculation

Weight of the gas $= x$ gms.
Weight of hydrogen $= y$ gms.
$\therefore$ Vapour density of the gas $= x/y$ gms.
$\therefore$ Molecular weight of the gas $= 2 \times$ vapour density

$$= 2 \times \frac{x}{y}$$

Problem - 1

The vapour density of sulphur-di-oxide is 32. What is its molecular weight ?

Molecular weight = 2 × vapour density.

Therefore molecular weight of sulphur-di-oxide
$= 2 \times 32 = 64.$

Therefore molecular weight of sulphur-di-oxide = 64.

Problem-2

At S.T.P., the weight of 400 ml. of carbon-di-oxide is 0·80 gm. At S.T.P., the weight of 500 ml. of hydrogen is 0·045 gm. Calculate the vapour density and molecular weight of carbon-di-oxide.

Weight of 400 ml of CO_2 at S.T.P. = 0·80 gm.

∴ Weight of 1000 ml. of CO_2 at S.T.P. $= \frac{0.80}{400} \times 1000$
= 2 gms.

Weight of 1000 ml. of hydrogen at S.T.P. $= 0.045 \times 2 = 0.09$ gm.

∴ Vapour density of CO_2 =

$$\frac{\text{Weight of 1000 ml. of } CO_2 \text{ at S.T.P.}}{\text{Weight of 1000 ml. of hydrogen at S.T.P.}} = \frac{2.0}{0.09} = 22.2.$$

Molecular weight of CO_2 = 2 × vapour density.
$= 2 \times 22.2 = 44.4$

Problem - 3

Calculate the vapour density of hydrogen sulphide
$(H = 1, S = 32)$

Molecular formula of hydrogen sulphide = H_2S

Molecular weight of hydrogen sulphide $= (2 \times 1) + 32 = 34$

∴ Vapour density of hydrogen sulphide

$$= \frac{\text{Molecular weight}}{2} = \frac{34}{2} = 17$$

Questions

1. Define : atomic weight and molecular weight.
2. Define the molecular weight of a substance with carbon-12 as its standard.
3. What do you mean by vapour density?
4. Arrive at the relationship between vapour density and molecular weight.
5. Describe the experiment to find the molecular weight of a gas using Regnault's method.

For Thought

In finding the molecular weight of a gas by Regnault's method, two identical flasks are used. Why can't we use a single flask ?

7. ACIDS, BASES AND SALTS

Chemical compounds are divided into several kinds. Of them acids, bases and salts are important.

Acids and Their Properties

Acids are useful chemical substances. The term acid means 'sour'. Fruits and some food stuffs that we use in our every day life, contain acids. That is why they are sour to taste. Some substances that we use in our every day life and acids contained in them are given below :

Substance	Acid
Apple	Malic acid
Lime	Citric acid
Grapes	Tartaric acid
Sour milk	Lactic acid

Gastric juice contains hydrochloric acid.

Kinds of Acids

Acids are classified into two kinds : 1. **Organic acids and 2. Mineral acids.**

Acetic acid, citric acid, malic acid, tartaric acid are examples of organic acids. Hydrochloric acid, nitric acid and sulphuric acid are mineral acids and they are used in the laboratories and so they are known as **'common acids'.**

Mineral acids are of two kinds. 1. Acids containing oxygen are known as **Oxy-acids.** Nitric acid and sulphuric acid are examples of oxy-acids. They are formed when non-metallic oxides dissolve in water. For example, sulphur tri-oxide dissolves in water forming sulphuric acid.

Acids like hydrochloric acid and hydrobromic acid do not contain oxygen. They are called **Hydracids.**

The following experiments reveal the common properties of acids:

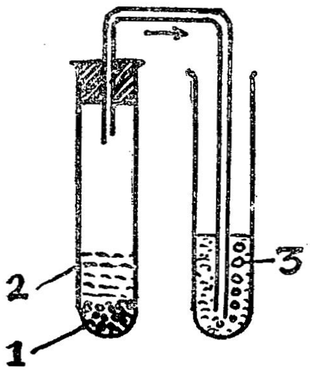
Taste of Acid : Experiment 1

Take a beaker and fill half of it with water. Add two or three drops of an acid and stir the solution. Taste the solution. It will be 'sour' to taste. Hence we learn that **acids are 'sour' to taste.**

Acids and Indicators : Experiment 2

Take three beakers of 100 ml. capacity. Pour dilute hydrochloric acid in each. Add blue litmus solution to the acid in the first beaker. Add methyl-orange to the acid in the second beaker. Add phenolphthalein to the acid in the third beaker. See whether any colour change takes place. You can observe that blue litmus changes into red; methyl-orange changes into pale red and phenolphthalein does not undergo any colour change. We learn that **acids turn blue litmus into red and methyl-orange into pale red but do not undergo any colour change with phenolphthalein.**

Action of an Acid with Sodium Carbonate : Experiment 3



Acid reacting with Carbonate
1. Sodium Carbonate
2. Hydrochloric acid
3. Clear lime water
Fig. 14

Take a small quantity of sodium carbonate, add a few drops of hydrochloric acid and observe what happens.

Then close the mouth of the test tube with a one holed stopper fitted with a delivery tube and fit the other end of the delivery tube into freshly prepared lime water taken in a beaker. Observe the liberation of a gas in the form of bubbles through the delivery tube and note that lime water changes into a milky solution.

$$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2O + CO_2 \uparrow$$

From this, we learn that **acids react with carbonates liberating carbon-di-oxide.**

Action of Acids with Metal : Experiment 4

Take a small quantity of dilute hydrochloric acid in a test-tube and put a small piece of zinc, magnesium or iron and observe what happens. The metal reacts with the acids liberating a gas.

Then close the mouth of the test tube with a one holed rubber stopper fitted with a delivery tube and collect the gas liberated in another test tube. Insert a burning splinter into the test tube containing the gas. The gas burns with a '*POP*' sound. This indicates that the liberated gas is hydrogen.

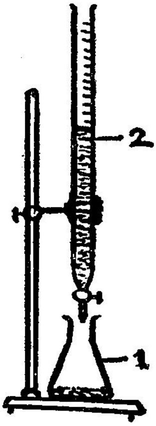
$$Mg + 2\ HCl \rightarrow MgCl_2 + H_2 \uparrow$$

From this experiment, we learn that **dilute acids react with metals like zinc, iron and magnesium, liberating hydrogen.**

Neutralisation of Acids by Bases : Experiment 5

Take hydrochloric acid in a burette fitted on a stand. Take a small quantity of sodium hydroxide solution in a beaker and add one or two drops of phenolphthalein to it. The solution will turn pink in colour.

Then add hydrochloric acid from the burette drop by drop to the sodium hydroxide solution in the beaker and stir the solution while adding the acid. After the addition of a certain quantity of the acid, the pink colour disappears. Just at that time stop adding hydrochloric acid. Pour the solution in the beaker in a porcelain dish. Evoporate the solution to dryness. Note that a white salt is left behind in the dish.

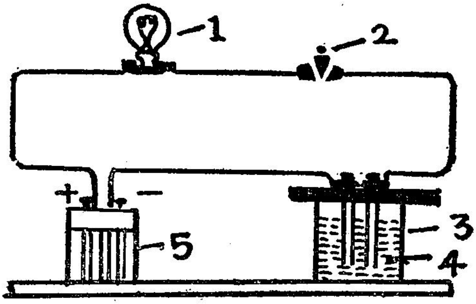


Neutralisation
1. Conical Flask
2. Burette
Fig. 15

$$NaOH + HCl \rightarrow NaCl + H_2O \uparrow$$

Hence, in general, **acids react with bases forming salt and water.**

Electrical conductivity of acids : Experiment 6



Electrical Conduction through Acids
1. Bulb 2. Key 3. Voltameter 4. Acid 5. Battery
Fig. 16

A battery, key, carbon voltameter and electric bulb are connected in series as shown in Fig. 16. Pour some dilute

sulphuric acid in the beaker in which carbon electrodes are immersed. Close the circuit by means of a key. As soon as the circuit is closed, observe what happens.

The filament of the bulb glows. The electrical circuit gets completed because of the sulphuric acid poured into the carbon voltameter and so the bulb glows. Observe the liberation of bubbles from the carbon electrodes. From this we learn that **acids are electrolytes that conduct electricity.**

From the above experiments we can define the term acids as follows :

"An acid is a substance that is sour to taste; that turns blue litmus into red; that contains hydrogen which will be displaced by metals; that reacts with carbonates liberating carbon-di-oxide; that produces salt and water with bases and that conduct electricity in solution".

Formation of Acids

Acids are formed in many ways and some of them are stated below :

1. Direct Combination of Elements

Acids are formed by the direct combination of constituent elements.

Example

Hydrogen combines with chlorine forming hydrogen chloride acid; hydrogen combines with bromine forming hydrogen bromide acid.

$$H_2 + Cl_2 \rightarrow 2\ HCl$$
$$H_2 + Br_2 \rightarrow 2\ HBr$$

2. Double Decomposition

When some salts are heated with concentrated sulphuric acid, acids are liberated.

Examples

(a) Hydrochloric acid

$$2\,NaCl + H_2SO_4 \xrightarrow{\Delta} Na_2SO_4 + 2\,HCl$$

(b) Nitric acid

$$NaNO_3 + H_2SO_4 \xrightarrow{\Delta} NaHSO_4 + HNO_3$$

3. **By dissolving non-metallic oxides**

Non-metallic oxides dissolve in water and produce acids. This can be demonstrated by the following experiments :

Experiment

Take three jars filled with oxygen. Place a piece of charcoal in a deflagrating spoon and burn the piece of charcoal in one jar containing oxygen. Similarly burn sulphur in the second jar and white phosphorus in the third jar. When the burning is over, add a small quantity of water in each jar and shake the jars well in order to dissolve the gases formed. Then add blue litmus solution to the resulting solution in each jar. Observe if there is any change in colour. Carbon, sulphur and phosphorus burn in oxygen and produce carbon-di-oxide, sulphur-di-oxide and phosphorus (V) oxide respectively.

$C + O_2$	$\longrightarrow$	$CO_2\uparrow$
$S + O_2$	$\longrightarrow$	$SO_2\uparrow$
$4\,P + 5\,O_2$	$\longrightarrow$	$2\,P_2O_5\uparrow$

These oxides dissolve in water forming carbonic acid, sulphuric acid and phosphoric acid respectively. They turn blue litmus solution into red.

$CO_2 + H_2O$	$\longrightarrow$	H_2CO_3
$SO_2 + H_2O$	$\longrightarrow$	H_2SO_3
$2\,P_2O_5 + 6\,H_2O$	$\longrightarrow$	$4\,H_3PO_4$

Oxides that thus dissolve in water forming acids are called acetic oxides and **acetic oxides** are also called **acid anhydrides** since they give acids with water.

Non-metallic oxides or acid anhydrides	Molecular formula	Name of the acid	Molecular formula
Sulphur-di-oxide	SO_2	Sulphurous acid	H_2SO_3
Carbon-di-oxide	CO_2	Carbonic acid	H_2CO_3
Sulphur (III) oxide	SO_3	Sulphuric acid	H_2SO_4
Phosphorous (V) oxide	P_2O_5	Phosphoric acid	H_3PO_4

Bases and its Properties

Substances that produce salts and water with acids are called bases. Since metallic oxides and metallic hydroxides react with acids producing salts and water, they are called bases. Ammonium hydroxide reacts with acids forming salt and water and so ammonium hydroxide is also a base.

Sodium oxide, potassium oxide and calcium oxide dissolve in water producing metallic hydroxides. **These hydroxides are called ' alkalis ' since they dissolve in water.**

$$K_2O + H_2O \rightarrow 2\,KOH$$
$$Na_2O + H_2O \rightarrow 2\,NaOH$$

Metallic oxides or hydroxides that do not dissolve in water but react with acids producing salt and water are called 'bases' Copper (II) oxides, xinc oxide and magnesium oxide are some. examples of bases.

All alkalis are bases but all bases are not alkalis

The reaction between an acid and a base is shown by the following equations :

MgO	$+ 2\,HCl$	$\rightarrow$	$MgCl_2$	$+ H_2O$
(oxide)	(acid)		(salt)	(water)
$Mg(OH)_2$	$+ 2\,HCl$	$\rightarrow$	$MgCl_2$	$+ 2\,H_2O$
(hydroxide)	(acid)		(salt)	(water)

Hence a **base is an oxide or hydroxide of a metal giving salt and water in the acids.** Let us study the properties of bases.

Taste of the base Experiment 1.

Take about 50 ml. of water in a beaker. Add about 0·5 gm. of sodium hydroxide and dissolve it in water. Take the solution in between the finger tips and feel the soapy touch by moving the fingers. Then place a drop of solution on the tongue and find its taste. The solution has a corrosive taste.

2. Bases and Indicator

Take three test tubes. Pour a small quantity of dilute sodium hydroxide in each. Add a few drops of red litmus in the first tube. Add methyl-orange in the second and phenolphthalein in the third. Note the colour changes. You may observe that **bases turn red litmus into blue; methyl-orange into yellow and phenolphthalein into pink colour.**

3. **Reaction of Acids with Bases :** Take about 5 ml. of water in a test tube. Dissolve about 0·5 gm. of sodium hydroxide in it. Add one or two drops of phenolphthalein to the solution. Then add dilute hydrochloric acid to the solution drop by drop till the solution becomes colourless. Now pour the solution into a porcelain dish and evaporate to dryness. Examine the residue left behind. The residue will be salty to taste.

Base + Acid → Salt + Water

From this you can learn that **bases undergo neutralisation with acids forming salt and water.**

4. Reaction of Alkalis with Ammonium Salts

Take about 3 ml. of sodium hydroxide solution in a test tube. Add about 3 ml. of ammonium chloride solution to it. Heat the solution if necessary. Observe the smell of the gas that comes out. Keep a moist red litmus paper near the mouth of the test tube and observe if there is any change in the colour.

Alkalis react with salts liberating ammonia and ammonia turns red litmus into blue.

5. Reaction of Alkalis with Metallic Salts

Take about 3 ml. of copper (II) sulphate solution in a test tube and add about 3 ml. of sodium hydroxide solution to it. Observe what happens. **Alkalis produce insoluble hydroxide from the solution of metallic salts.**

6. Electrical Conductivity of Bases

A battery, key, carbon voltameter and electric bulb are connected in series as shown in Fig. 16. A small quantity of sodium hydroxide solution is poured into the beaker. Plug in the key and complete the circuit. As soon as the circuit is completed, you can see that the bulb glows. The circuit gets completed because of the sodium hydroxide solution in the carbon voltameter and so the bulb glows. In addition, you can observe that gases are being liberated from the carbon electrodes. From this experiment you can conclude that **bases are electrolytes which conduct electricity.**

From the above experiments, we can define a base as follows :

" **Bases are metallic oxides or hydroxides which react with acids forming salt and water which turn red litmus into blue and which conduct electricity in solution**".

Kinds of Alkalis

Alkalis are classified into two kinds : (1) **Caustic alkalis** and (2) **Mild alkalis.** Sodium hydroxide and potassium hydroxide are caustic alkalis because they destroy clothes, paper, wood etc. Calcium hydroxide and ammonium hydroxide which do not have the property of caustic alkali are mild alkalis.

Arrhenius Theory of Acids and Bases

According to Arrhenius, electrolytes when dissolved in water dissociate into oppositely charged particles called ions.

For example, sodium chloride dissolves in water giving positively charged sodium ion and negatively charged chloride ion.

$$NaCl \longrightarrow Na^{+} + Cl^{-}$$

Acid and bases are electrolytes. Hence they also dissolve in water and break up into ions. According **to Arrhenius theory. Acids are compounds which dissolve in water to yield hydrogen ions.**

For example, hydrogen chloride dissolves in water and breaks up to give hydrogen ion. So hydrogen chloride is an acid.

$$HCl \longrightarrow H^{+} + Cl^{-}$$
$$H_2SO_4 \longrightarrow 2\,H^{+} + SO_4^{-2}$$
$$HNO_3 \longrightarrow H^{+} + NO_3^{-}$$

Therefore acids are donors of hydrogen ions. Similarly bases are substances which dissolve in water and dissociate to give hydroxyl ions.

$$NaOH \longrightarrow Na^{+} + OH^{-}$$
$$KOH \longrightarrow K^{+} + OH^{-}$$

Hence bases are donors of hydroxyl ions.

Salts

In our every day life, the term 'salt' refers only to the common salt which is sodium chloride. In Chemistry, **salts are the substances formed as a result of the chemical reaction of acids with bases. Salts are formed by the displacement of one or more hydrogen atoms from acids by metals or ammonium radical.**

Kinds of Salts

Salts are of different kinds like **normal salts, acid salts basic salts, double salts, complex salts, etc.**

Formation of Salts

1. Formation of Salt by adding a Metal to an Acid

When zinc is added to dilute sulphuric acid, zinc sulphate solution is formed. The hydrogen in the acid is displaced by the metal.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

A salt can be formed when a metallic oxide reacts with an acid. Then the oxygen in the metallic oxide will react with the hydrogen in the acid forming water.

$$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2$$

2. Formation of Salts by the neutralisation of Acids with Alkalis :

When acids are added to alkalis like sodium hydroxide and potassium hydroxide, salt and water are formed. This reaction is called neutralisation.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

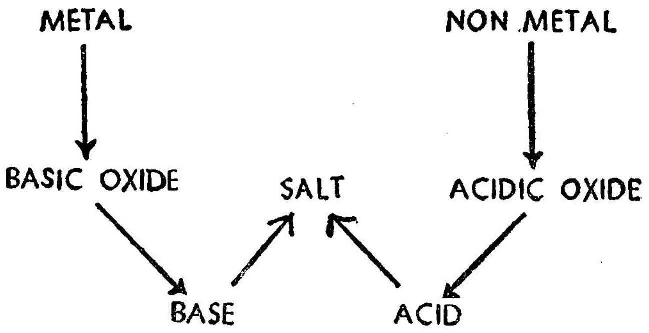
3, Formation of Salts by adding Acids to Carbonates

When an acid is added to carbonate salt, carbon-di-oxide and water are formed. Carbon-di-oxide will escape as gas and salt will remain in the solution. The salt is obtained by evaporating the solution.

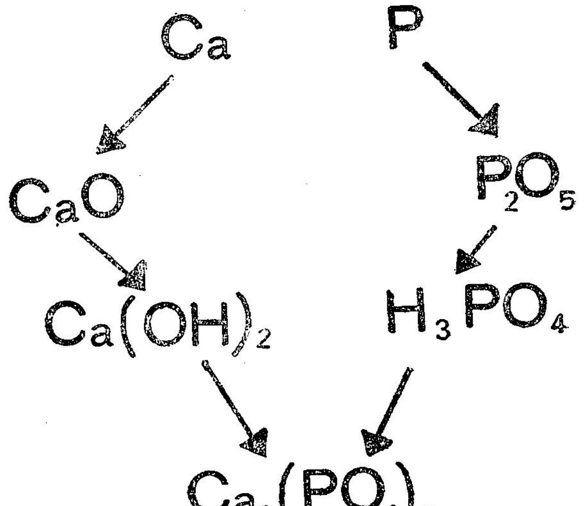
$$Na_2CO_3 + 2\,HCl \rightarrow 2\,NaCl + CO_2 + H_2O$$

Naming of Salts

In the name of a salt, the prefix will indicate the metal or the base and the suffix will indicate the acid from which the salt is formed. For example, copper-oxide reacts with sulphuric acid forming copper sulphate. Copper is the metallic part. The term sulphate indicates the acid by which the salt is produced. Salts produced by sulpuric acid are called sulphates. Hydrochloric acid produces chlorides and the salts obtained from nitric acid are called nitrates.



Formation of Salt
Fig. 16-*a*



Formation of Salt–Example
Fig. 16-*b*

Strong and Weak Acids and Bases

You know that acids and bases react to form salts and water. Hydrochloric acid, sulphuric acid and nitric acid are called strong acids. Similarly, sodium hydroxide and potassium hydroxide are called strong bases.

Carbonic acid, acetic acid are called weak acids. Ammonium hydroxide, iron (III) hydroxide, Aluminium hydroxide, Magnesium hydroxide are called weak bases.

1. Sodium chloride is formed by the reaction of a strong acid with a strong base.

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

2. Sodium carbonate is formed by the reaction of a strong base with a weak acid namely carbonic acid.

$$2\ NaOH + H_2CO_3 \longrightarrow Na_2CO_3 + H_2O$$

Iron (III) chloride is formed by the reaction of the weak base iron (III) hydroxide and strong acid hydrochloric acid.

$$Fe(OH)_3 + 3\ HCl \rightarrow FeCl_3 + 3\ H_2O$$

Hydrolysis of Salts

Take three test tubes containing sodium chloride solution, sodium carbonate solution and iron (III) chloride solution respectively. Test each solution with blue litmus and red litmus paper and study their acidic and basic properties.

Sodium chloride solution will not produce any change either with blue litmus or red litmus paper. The solution is neutral to litmus and so it does not react with water.

Sodium carbonate will turn red litmus solution into blue. Why ?

Sodium carbonate is a salt but its solution is basic. The reason is sodium chloride reacts with water forming a strong base and a weak acid.

$$\underset{\text{(Salt)}}{Na_2CO_3} + \underset{\text{(Water)}}{H_2O} \rightarrow \underset{\text{(Base)}}{2\ NaOH} + \underset{\text{(Acid)}}{H_2CO_3}$$

Iron (III) chloride solution will be acidic in nature and and it will turn blue litmus into red. It undergoes hydrolysis with water forming a weak base and a strong acid.

$$FeCl_3 + 3\,H_2O \longrightarrow Fe(OH)_3 + 3\,HCl$$
(Salt) (Water) (Base) (Acid)

In hydrolysis, the salt interacts with water producing an acid and a base. The reaction of acid with a base forming salt and water is called neutralisation. The reaction of a salt with water producing an acid and a base is called hydrolysis. Hence, hydrolysis is the reverse reaction of neutralization.

We learn the following from the above experiments:

1. Salts like sodium chloride and potassium nitrate formed by the reaction of strong acids like hydrochloric acid and nitric acid with strong bases like sodium hydroxide and potassium hydroxide do not undergo hydrolysis and therefore their solutions are neutral to litmus.

2. Salts like sodium carbonate and potassium carbonate formed by the reaction of strong bases like sodium hydroxide and potassium hydroxide with weak acids like carbonic acid and acetic acid undergo hydrolysis producing strong bases like sodium hydroxide and potassium hydroxide and so their solutions are basic in nature.

3. Salts like iron (III) chloride and aluminium sulphate formed by the reaction of weak bases like ammonium hydroxide and iron (III) hydroxide with strong acids like hydrochloric acid and sulphuric acid undergo hydrolysis producing strong acids like hydrochloric acid and sulphuric acid and so their solutions are acidic in nature.

Questions

1. Mention the common acids largely used in the laboratory.
2. What is an acid ?
3. Name the kinds of acids with examples.
4. Give the general properties of acids.
5. What are bases ? Give examples.
6. What are alkalis ? Give examples.

7. Name the kinds of alkalis.
8. State the general properties of bases.
9. Describe the experiment to show that the solutions of acids and bases conduct electricity.
10. Mention two mild alkalis.
11. What are salts ?
12. State the different methods of preparing salts with examples for each.
13. How are salts named ?
14. What is neutralisation ?
15. What is hydrolysis ? Mention the kinds of salts that undergo hydrolysis. Give examples.
16. Define the terms acid and base based on Arrhenius theory.

Know Yourself

In English the term Alkali is derived from the Arabic word Al-kali which means 'ash'. Alkalis were first prepared from the ashes produced by the burning of fire wood.

For Thought

1. Aluminium sulphate is a salt. But its solution in water is acidic and it turns blue litmus to red. Why ?

2. When soap is applied on a cloth stained by turmeric, it turns red. Why?

8. CHLORINE

Molecular Symbol : Cl_2 **Molecular weight :** 70·92

Like oxygen and hydrogen, chlorine is also an element in the gaseous state. In 1810, a scientist by name **Davy** proved that chlorine is an element. He gave it the name of **'chlorine'** meaning **'greenish yellow'**. In 1774, **Sheele** prepared chlorine first by heating manganese-di-oxide with strong hydrochloric acid. In 1915, during the First World War, the Germans used chlorine to suffocate the enemies.

Occurrence in Nature

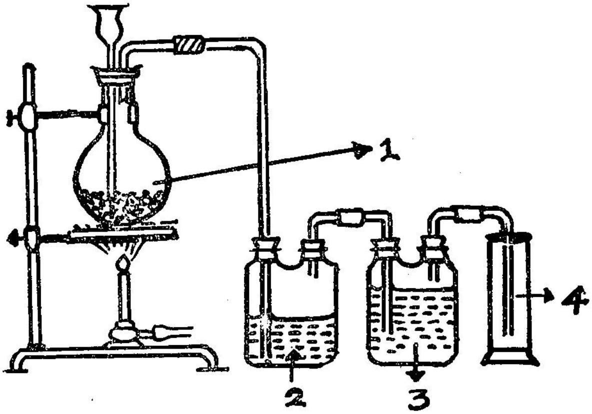
Since chlorine is a highly reactive element, it does not occur in the free state. Chlorine is a constituent of sodium chloride, potassium chloride, calcium chloride and magnesium chloride that are found dissolved in sea water. The most important compound of chlorine is **sodium chloride** which is of great use in our day to day life as well as in chemical industries.

Preparation of Chlorine

On a large scale chlorine is manufactured by the Castner-Kelner process. In this method brine solution (a solution of sodium chloride) undergoes electrolysis and chlorine is liberated at the anode.

Laboratory Method of Preparation of Chlorine

Chlorine is prepared from hydrochloric acid. This acid is a compound of hydrogen and chlorine. Chlorine can be obtained by the oxidation of hydrochloric acid. In the labo-



Preparation of chlorine

1. Manganese-di-oxide + Con. Hydrochloric Acid 2. Water 3. Con. Sulphuric Acid 4. Chlorine

Fig. 17

ratory, manganese-di-oxide is heated with hydrochloric acid to oxidise hydrochloric acid.

The apparatus is set up as shown in Fig. 17. Manganese -di-oxide is taken in a round bottomed flask fitted with a two holed rubber stopper. Through one hole a thistle funnel is inserted with its tip touching the bottom of the flask. Through the other hole a delivery tube is passed. The other end of the delivery tube is connected to a wash bottle containing water. The outlet tube from the wash bottle is connected to a second wash bottle containing strong sulphuric acid. Now the outlet tube from the second wash bottle is kept inside a gas jar. Now strong hydrochloric acid is poured into the flask thorough the thistle funnel and the flask is heated. Strong hydrochloric acid reacts with manganese-di-oxide and liberates chlorine. Manganese chloride and water are formed in the reaction.

$$MnO_2 + 4\,HCl \xrightarrow{\Delta} MnCl_2 + 2\,H_2O + Cl_2 \uparrow$$

Chlorine gas liberated from the flask contains traces of hydrogen chloride gas. When the gas passes through the wash bottle containing water, the more soluble hydrogen chloride completely dissolves in water. Since chlorine is only sparingly soluble in water, it does not dissolve much. The undissolved, moist chlorine passes through the second wash bottle containing strong sulphuric acid, all the moisture in chlorine will be absorbed by the sulphuric acid. The pure and outcoming dry chlorine is collected in the gas jar by the upward displacement of air.

Note

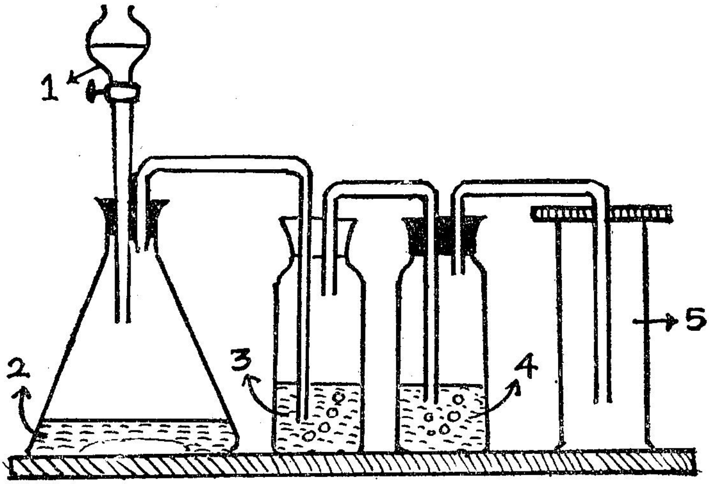
Chlorine can also be prepared by heating a mixture of manganese-di-oxide, sodium chloride and strong sulphuric acid. This is similar to the method as described above.

Preparation of Pure Chlorine

In order to prepare pure chlorine at ordinary temperature, strong hydrochloric aeid is oxidised by potassium permanganate crystals.

$$2\,KMnO_4 + 16\,HCl \rightarrow 2\,KCl + 2\,MnCl_2 + 8\,H_2O + 5\,Cl_2 \uparrow$$

In this method pure chlorine is liberated even without heating.



Preparation of Chlorine
1. Con. Hydrochloric Acid 2. Potassium Permanganate
3. Water 4. Con. Sulphuric Acid 5. Chlorine
Fig. 18

Chlorine is passed through water to remove hydrogen chloride. Then it is bubbled through concentrated sulphuric acid to remove moisture. The pure, dry chlorine is collected in the gas jar by the upward displacement of chlorine.

Physical Properties of Chlorine.

This is a greenish yellow gas. It is soluble in water and the solution of chlorine in water is known as 'Chlorine Water'. It is $2\frac{1}{2}$ times heavier than air. It has a pungent odour. When chlorine is inhaled, the soft mucous membranes in our nose and throat will be destroyed.

Chemical Properties of Chlorine

Reaction with elements : Chlorine is very highly reactive. So it directly combines with metals and non-metals to form chlorides.

Non-metals : (1) A jar of hydrogen is inverted over a jar of chlorine and the arrangement is kept in sunlight. These two gases combine with a loud explosion to form hydrogen chloride.

$$H_2 + Cl_2 \rightarrow 2\,HCl$$

(2) When a piece of white phosphorus is kept in a deflagrating spoon and introduced into a jar of chlorine, it burns with a bright flame forming phosphorus (III) chloride.

$$2\,P + 3\,Cl_2 \rightarrow 2\,PCl_3$$

Reaction with Metals

(1) When heated antimony powder is sprinkled into a jar of chlorine, it burns with sparkling brightness to give dense, white fumes of poisonous antimony (III) chloride.

$$2\,Sb + 3\,Cl_2 \rightarrow 2\,SbCl_3$$

(2) When a piece of sodium in a deflagrating spoon is introduced into a jar of chlorine, it burns with a bright yellow flame to give sodium chloride.

$$2\,Na + Cl_2 \rightarrow 2\,NaCl$$

(3) When a heated copper foil is introduced into a jar of chlorine, copper burns in chlorine to give copper chloride.

$$Cu + Cl_2 \rightarrow CuCl_2$$

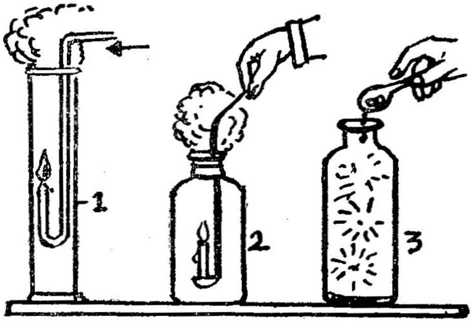
Affinity for Hydrogen

Chlorine has a great affinity for hydrogen. This can be illustrated by the following experiments:

(1) When a filter paper soaked in warm turpentine is introduced into a jar of chlorine, white fumes of hydrogen chloride are formed with carbon depositing on the paper. Since chlorine combines with the hydrogen in turpentine, carbon is left out.

$$C_{10}H_{16} + 8\,Cl_2 \rightarrow 10\,C + 16\,HCl \uparrow$$

(2) When a burning candle is introduced into a jar of chlorine, it continues to burn with a dull flame. Black clouds of soot are produced. Chlorine combines with the hydrogen of the candle and carbon is displaced. These two experiments clearly show the affinity of chlorine for hydrogen.



Chemical Properties of Chlorine
1. Burning of Hydrogen 2. Burning of Candle
3. Burning of Antimony
Fig. 19

Reaction with Caustic Alkalis

The reaction of chlorine with alkalis depends upon the concentration of the alkalis and the temperature of the reaction.

(1) Chlorine reacts with cold, dilute sodium hydroxide to give the chloride and hypochlorite of sodium.

$$2\ NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$$

(2) Chlorine reacts with hot, concentrated sodium hydroxide to give the chloride of sodium and chlorates.

$$6\ NaOH + 3\ Cl_2 \rightarrow 5\ NaCl + NaClO_3 + 3\ H_2O$$

Chlorine reacts similarly with potassium hydroxide.

Formation of Bleaching Powder

When chlorine is passed over dry slaked lime, it absorbs chlorine and forms bleaching powder. Dry slaked lime is spread on perforated plates in a chamber. When chlorine is passed through the chamber, bleaching powder is formed.

The temperature of the chamber is kept at 30°C—40°C and the reaction takes about 24 hours for its completion.

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

Bleaching powder is a white powder with the smell of chlorine. It is used to bleach cotton fabrics and as a disinfectant.

Bleaching Action of Chlorine

When some coloured moist flowers are put in a jar of chlorine, they get bleached after some time. Hence chlorine is a bleaching agent. What is the reason for this bleaching action ? Chlorine combines easily with the hydrogen in water particles and oxygen is released in the **nascent state.** This nascent oxygen is extremely reactive and powerful. This nascent oxygen is in the atomic state and hence it is very powerful. It oxidises the coloured materials. Hence they get bleached.

$$Cl_2 + H_2O \rightarrow HClO + HCl$$
$$HClO \rightarrow HCl + (O)$$
$$(O) + \text{colour} \rightarrow \text{colourless product}$$

The bleaching action of chlorine is its oxidising property.

Displacement Reactions

Chlorine displaces bromine from a solution of potassium bromide and the solution turns yellow.

$$2\,KBr + Cl_2 \rightarrow 2\,KCl + Br_2 \uparrow$$

Chlorine displaces iodine from potassium iodine and the solution becomes brown.

$$2\,KI + Cl_2 \rightarrow 2\,KCl + I_2$$

Both these reactions show that **chlorine is more reactive than bromine and iodine.**

How to identify Chlorine?

1. It can be identified by its greenish yellow colour or its characteristic pungent odour.

2. It bleaches coloured moist flowers.

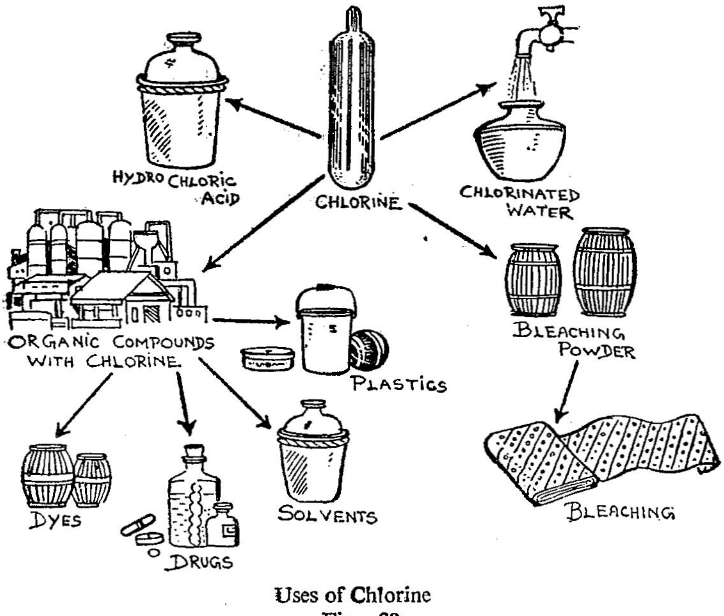
3. It turns starch iodine paper dark blue (Starch iodide paper is starch paper soaked in potassium iodide solution. Chlorine displaces iodine from potassium iodide. The displaced iodine combines with starch to give a blue colour).

Uses of Chlorine

1. Chlorine is largely used in the manufacture of bleaching powder.

2. It is used in the preparation of potassium chlorate, sodium chlorate, chloroform and such other useful compounds.

3. It is employed for destroying the germs in the drinking water.



Uses of Chlorine
Fig. 20

4. Nowadays chlorine is used in the industrial manufacture of hydrogen chloride.

5. In the weaving industry chlorine is used to bleach the cotton fabrics.

6. Chlorine is used in the extraction of gold from its ore.

7. It is used as a bleaching agent for wood pulp, rough cloth and paper.

8. It is greatly used in the manufacture of medicines, insecticides and poisonous gases.

Halogens

Elements like fluorine, chlorine, bromine and iodine combine with metals to form salts. Such salts resemble the salts like sodium chloride, magnesium chloride etc., which are obtained from sea-water.

As these four elements give rise to a lot of salts, they are termed 'Halogens' meaning 'Salt Producers'.

Therefore fluorine, chlorine, bromine and iodine belong to the family of halogens. In the periodic table this family occupies VII-A group.

1. Since all the four elements belong to the same family, they show resemblance in their physical and chemical properties.

2. As the atomic weight increases, there is a gradation in their properties.

The properties of the halogens from fluorine to iodine are listed below in the table:

Property	Fluorine	Chlorine	Bromine	Iodine
1. Atomic weight	19	35·45	79·91	126·92
2. Atomic number	9	17	35	53
3. Physical state	Gas	Gas	Liquid	Solid
4. Colour	Pale greenish yellow	Greenish yellow	Orange	Violet
5. Valency	One	One	One	One
6. Solubility in water	Slightly soluble	Slightly soluble	Not so soluble	Least soluble
7. Reaction with hydrogen	Very Highly reactive	Highly reactive	Reaction takes place only on heating	Reaction takes place only at very high temparature
8. Reaction with metals	Very quick recaction	Quick reaction	Slow reaction	Not easily reactive

Questions

1. Why is chlorine not found in the free state?
2. Mention some compounds of chlorine found in nature.
3. How is chlorine prepared on large scale?
4. Describe with a sketch the preparation of chlorine in a laboratory.
5. What are the physical properties of chlorine?
6. Give two experiments to show that chlorine has great affinity for hydrogen.
7. How does phosphorus react with chlorine?
8. Give two examples to show that chlorine reacts with metals.
9. Why does chlorine not bleach printed letters?
10. How will you show that chlorine bleaches vegetable colours?
11. Mention the process by which chlorine removes vegetable colours.
12. How will you know that chlorine is more reactive than iodine?
13. Give the tests to identify chlorine.
14. How is bleaching powder prepared from chlorine?
15. Mention the uses of chlorine.
16. What are halogens? Why are they called so ?
17. Tabulate the properties of halogens.

For Thought

Chlorine does not combine with carbon. Carbon tetra chloride is a compound containing the elements chlorine and carbon. How do you account for this?

Know Yourself

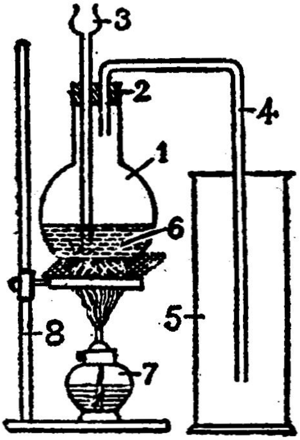
Printing ink contains carbon. Chlorine does not react with carbon. Hence, chlorine does not bleach printed matter or matter written with pencil.

9. HYDROGEN CHLORIDE AND CHLORIDE SALTS

Molecular formula : HCl. **Molecular weight : 36·46**

Hydrogen Chloride

The chemical name of hydrochloric acid is hydrogen chloride. In 1658, a scientist by name **Glauber** combined common salt with strong sulphuric acid to get a gas which when dissolved in water yielded hydrochloric acid. As this acid was got from common salt, this was named **"Muriatic acid"**.



Preparation of Hydrogen Chloride gas
1. Flask 2. Double holed Cork 3. Thistle Funnel 4. Delivery Tube 5. Gas Jar 6. Sodium Chloride + Con. Sulphuric Acid 7. Spirit Lamp 8. Stand
Fig 21

Lavoiser considered that oxygen was one of the essential constitutents of all acids. **Davy** proved in 1810 that hydrochloric acid was a compound of hydrogen and chlorine only and it did not contain oxygen.

Preparation of Hydrogen Chloride Gas

Sodium chloride solid is taken in a round bottom flask fitted with a two holed rubber stopper. Through one hole, a thistle funnel is inserted, the tip of which is kept touching the bottom of the flask. Through the other hole passes a delivery tube. Now **strong sulphuric acid** is poured into the flask through the thistle funnel. The flask is heated. A vigorous reaction takes place and hydrogen chloride is formed. The gas that comes out through the delivery tube gets collected in the gas jar by the upward displacement of air because this gas is heavier than air.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl \uparrow$$
$$2\,NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\,HCl$$

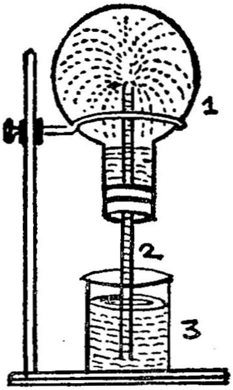
Note : If pure, dry gas is required, the outcoming gas is passed through a wash bottle containing strong sulphuric acid. Concentrated sulphuric acid absorbs the moisture. The dry hydrogen chloride is collected in jars by the upward displacement of air.

Physical Properties of the Gas

Hydrogen chloride is a colourless gas with a pungent odour. It is heavier than air. It fumes in moist air. It is freely and highly soluble in water. At $0^{\circ}C$, 1 ml. of water can dissolve 500 ml. of the gas. The high solubility of hydrogen chloride in water can be demonstrated by the fountain experiment.

Experiment

Hydrogen chloride gas is collected in a dry flask fitted with a one-holed rubber stopper. Through the hole a jet tube is inserted the tip of which is inside the flask. The free end of the tube is kept well under the level of blue litmus solution in a beaker. The set up should be as shown in Fig. 22. In a short time the blue litmus solution rises up in the tube and flashes into the flask in a fine jet. It also turns red in colour. What is the reason? Hydrogen chloride gas has great affinity for water and hence the litmus solution gets into the flask. Water dissolves a large amount of hydrogen chloride gas. So the pressure is reduced inside the flask. Due to the external atmospheric pressure, the blue litmus solution further rises into the tube and flashes into the flask in the form of a jet. When hydrogen chloride dissolves in water, hydrochloric acid is formed and hence the blue litmus is turned red inside the flask.



Solubility of Hydrogen Chloride
1. Flask filled with Hydrogen Chloride Gas 2. Jet tube 3. Blue Litmus solution
Fig. 22

Chemical Properties

1. When a blue litmus paper dipped in water is introduced into a jar of hydrogen chloride, it turns red in colour, because

hydrogen chloride gas is acidic and it produces hydrochloric acid when dissolved in water.

2. A small droplet of silver nitrate solution is taken in a tube and it is introduced into a jar of hydrogen chloride. This gas reacts with silver nitrate to give a curdy white precipitate of silver chloride.

$$HCl + AgNO_3 \rightarrow AgCl \downarrow + HNO_3$$

3. A jar of ammonia is inverted over a jar of hydrogen chloride. When hydrogen chloride reacts with ammonia, ammonium chloride is formed. It appears in the form of dense white fumes in the glass jar.

$$NH_3 + HCl \rightarrow NH_4Cl$$

4. A small piece of sodium is taken in a deflagrating spoon. It is heated and the burning sodium is introduced into the jar of hydrogen chloride gas. Burning sodium continues to burn. In this reaction sodium chloride and hydrogen are formed.

$$2\,Na + 2\,HCl \rightarrow 2\,NaCl + H_2 \uparrow$$

Test for the Gas

1. When a glass rod dipped in ammonium hydroxide is introduced into a jar of hydrogen chloride, dense white fumes of ammonium chloride are formed.

2. This gas reacts with silver nitrate to give a curdy white precipitate of silver chloride.

Uses of Hydrogen Chloride

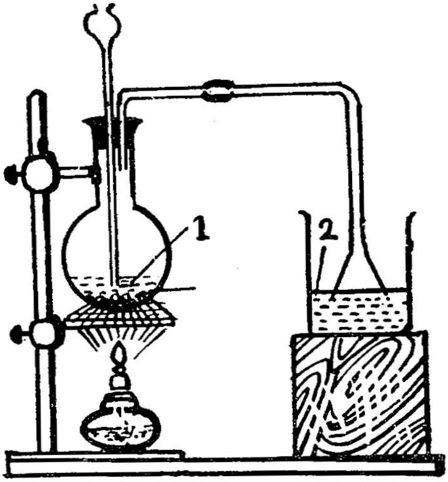
Hydrogen chloride gas dissolves in water to give hydrochloric acid. This acid is widely used in industries and laboratories.

Hydrochloric Acid

When hydrogen chloride gas is dissolved in water, hydrochloric acid is got. Hydrogen chloride is highly soluble in water. So the following method is adopted to get hydrochloric acid by dissolving the gas in water :

Preparation of Hydrochloric Acid

As described previously, hydrogen chloride gas is prepared in the laboratory. The outcoming gas is led through the



Preparation of Hydrochloric Acid

1. Sodium chloride + Con. Sulphuric acid 2. Water

Fig. 23

delivery tube to the tip of which a wide-mouthed funnel is attached. The mouth of the funnel is kept touching the level of water in a beaker. In this position hydrogen chloride gas is passed through water. Hydrogen chloride dissolves in the water to give hydrochloric acid.

Physical Properties

Hydrochloric acid is a colourless acid that fumes in moist air. It has a pungent odour. It is easily volatile. It tastes sour.

Chemical Properties

(a) General Characteristics

1. Hydrochloric acid reacts with metals to give the metallic chlorides and hydrogen.

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2 \uparrow$$
$$Mg + 2\,HCl \rightarrow MgCl_2 + H_2 \uparrow$$

2. Hydrochloric acid reacts with metallic oxides, hydro-oxides and carbonates as given below.

$$MgO + 2\,HCl \rightarrow MgCl_2 + H_2O$$
$$NaOH + HCl \rightarrow NaCl + H_2O$$
$$CaCO_3 + 2\,HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow$$

(b) Special Properties

(1) A small amount of silver nitrate solution is taken in a test-tube, and hydrochloric acid is added to it. A curdy white precipitate of silver chloride is formed.

$$AgNO_3 + HCl \rightarrow AgCl \downarrow + HNO_3$$

(2) A small amount of manganese-di-oxide is added to strong hydrochloric acid taken in a test tube. The tube is heated. Greenish yellow chlorine gas is evolved.

$$MnO_2 + 4\,HCl \xrightarrow{\Delta} MnCl_2 + 2\,H_2O + Cl_2 \uparrow$$

(3) A small quantity of hydrochloric acid is taken in a test tube. A solution of lead nitrate is added to it. A white precipitate of lead chloride is obtained. On heating, the precipitate dissolves in hot water. The precipitate reappears on cooling the solution.

$$Pb\,(NO_3)_2 + 2\,HCl \rightarrow PbCl_2 \downarrow + 2\,HNO_3$$

Test for Hydrochloric Acid

From the above three experiments, hydrochloric acid can be identified.

Uses of Hydrochloric Acid

1. It is used in the preparation of chlorine and metallic chlorides.

2. A mixture of three parts by volume of strong hydrochloric acid and one part by volume of strong nitric acid is known as **Aqua regia.** This aqua regia easily dissolves noble metals such as silver, gold, platinum etc. which are not soluble in other acids.

3. It is used for pickling iron sheets in order to coat them with zinc and tin.

4. It is useful in calico printing and dyeing industry.

5. This is very useful reagent in a laboratory.

Chlorides

Those compounds which are formed by the combination of chlorine with metals are generally known as chlorides.

Formation of Chlorides

1. Chlorine directly combines with certain metals to give chlorides. For example when sodium burns in chlorine, sodium chloride is formed.

$$2\,Na + Cl_2 \rightarrow 2\,NaCl$$

2. Some metals or their oxides or their hydroxides or their carbonates react with hydrochloric acid to give chlorides. Some examples are given below:

$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2 \uparrow$
$MgO + 2\,HCl \rightarrow MgCl_2 + H_2O$
$NaOH + HCl \rightarrow NaCl + H_2O$
$CaCO_3 + 2\,HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow$

Physical Properties of Chlorides

Mostly chlorides are white in colour. Some are blue. Many of the chlorides are soluble in water. But lead chloride and silver chloride are insoluble in water.

Chemical Properties

1. Generally when chlorides are heated with strong sulphuric acid, hydrogen chloride gas is formed.

$$NaCl + H_2SO_4 \xrightarrow{\Delta} NaHSO_4 + HCl \uparrow$$

2. When a chloride mixed with an oxidising agent like manganese-di-oxide is heated with strong sulphuric acid, chlorine gas is obtained.

$$2\,NaCl + MnO_2 + 2\,H_2SO_4 \xrightarrow{\Delta} Na_2SO_4 + MnSO_4 + 2\,H_2O + Cl_2 \uparrow$$

Test for a Chloride

A chloride salt can be tested and identified by its reaction with silver nitrate solution. Some chloride salt is dissolved in distilled water and to that one ml. of silver nitrate solution is added. Curdy white precipitate of silver chloride is got.

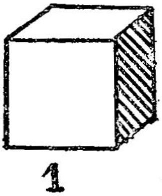
$$NaCl + AgNO_3 \rightarrow AgCl \downarrow + NaNO_3$$

This precipitate is soluble in excess ammonium hydroxide. But insoluble in dilute nitric acid.

Sodium Chloride Crystal

The sodium chloride crystal is cubical in shape. This is its external appearance.

Structure of the Crystal



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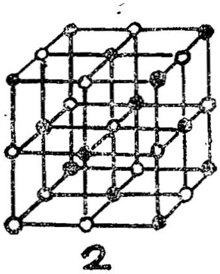

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1. External Appearance 2. Internal Structure

Fig. 24

With the help of X-rays, the internal structure of the crystal has been studied. The crystal contains positively

charged sodium ions and negatively charged chloride ions lying alternately. The ions possess opposite electrical charges. Hence, they are attracted towards each other by electrostatic forces. This electrical attractive force stabilises the structure of the crystal.

Bleaching Powder

The preparation of bleaching powder has already been explained in the chapter on "**Chlorine**". Let us study the properties and uses of bleaching powder.

Properties

It is a moist white powder. It has the odour of chlorine. It reacts with dilute acids to give chlorine.

$$CaOCl_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O + Cl_2 \uparrow$$

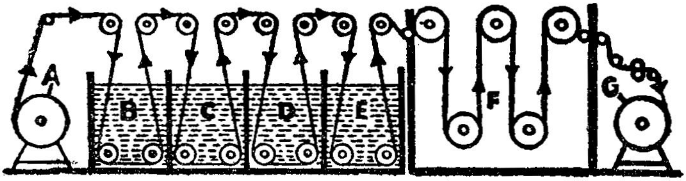
Uses

1. It is used in bleaching fabrics and wood pulp.

2. It is used as a disinfectant and employed in the parification of drinking water.

Bleaching Fabircs with Bleaching Powder

Coloured fabrics to be bleached are first drenched in a solution of bleaching powder. Then they are kept soaked in a dilute acid. This acid will react with the bleaching powder and liberate chlorine. This chlorine bleaches the fabrics.



A. Umbleached Cloth B. Bleaching Powder Solution C. Dilute Acid Solution D. Solution of Antichlorine E. Washing Bath F. Drying G. Bleaching Cloth

Fig. 25

Thus the bleached fabrics are then completely washed in pure water. Moreover, things washed by chlorine may con-

tain traces of chlorine left behind. This chlorine may spoil the clothes. So to remove this chlorine, the washed clothes are soaked in a solution of hypo (sodium thiosulphate) and then dried.

Antichlors

Clothes washed by bleaching powder or chlorine may contain traces of chlorine left behind. This excess chlorine from the clothes is removed by soaking the clothes in a solution of sodium thiosulphate, sulphur-di-oxide, hydrogen peroxide or sodium sulphite, such compounds which are capable of removing this excess chlorine are known as **antichlors.**

Questions

1. Describe with a neat diagram the laboratory method of preparation of hydrogen chloride gas.
2. Mention the physical properties and chemical properties of hydrogen chloride.
3. How does ammonia react with hydrogen chloride ?
4. What is the reaction of hydrogen chloride on silver nitrate ?
5. How is hydrochloric acid prepared in the laboratory ? Draw a diagram and explain.
6. Write down the physical and chemical properties of hydrochloric acid ?
7. What are the characteristic properties of hydrochloric acid ?
8. Give the chemical name of hydrochloric acid.
9. Mention the uses of hydrochloric acid.
10. What is aqua regia ? Give its uses.
11. Write down the tests for hydrochloric acid.
12. Describe the experiment to show the high solubility of hydrogen chloride in water.
13. Describe with examples the methods of formation of chlorides.

14. Give examples of insoluble chlorides.
15. How can chlorine be got from chlorides ?
16. How are chlorides tested ?
17. Describe the internal structure of sodium chloride crystals.
18. How is bleaching powder prepared ?
19. Give the properties and uses of bleaching powder.
20. Give the chemical name and the molecular formula of the bleaching powder.

For Thought

Concentrated hydrochloric acid fumes in air. When we belch, we feel a sour taste.

Impure hydrochloric acid is yellow in colour.

10. SULPHUR

Symbol: S **Atomic No. 16. Atomic weight 32·06. Valency 2,4,6**

Sulphur had been in use in our country from ancient times. The Sanskrit word for sulphur is "**Sulvari**" which means "Copper's Enemy" or the enemy of copper. The name was transformed to "**Sulphuricam**" in Latin. It became sulphur in English. **Charaka**, the ayurvedic physician, has mentioned the various uses of sulphur in his book "**Cikitsa**" **Lavoisier** was the first to recognise the elementary nature of sulphur. There were many evidences to conclude that the Chinese had been using sulphur for the preparation of gun powder from very early times.

Occurrence

Large quantities of sulphur occur in the free state in the volcanic regions of Sicily and Japan and in the districts of Texas and Louisiana in the U.S.A. The sulphide ores and the sulphate ores which occur in nature are all compounds containing sulphur. The sulphates namely gypsum, epsum and glauber salt occur in plenty in nature.

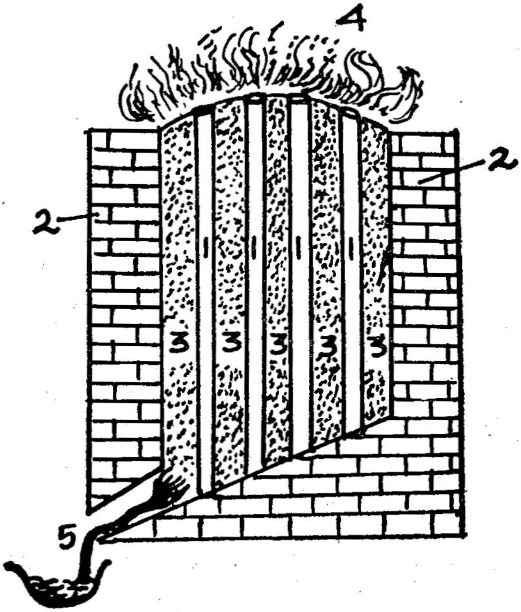
(i) Iron Pyrites (FeS_2)
(ii) Zinc Blende (ZnS)
(iii) Galena (PbS) are the naturally occuring sulphides.

Extraction of Sulphur

In some places sulphur is found on the ground surface or a little deep under the ground. In such places, the Sicilian process is adopted in extracting sulphur. In other places, it is found very deep under the ground below the rocks as solid sulphur deposits. Frasch process is used to extract sulphur in these places.

1. Sicilian Process

In volcanic regions, the sulphur is mixed with soil and rocky impurities. The sulphur ore is excavated from the surface of the ground and filled in sulphur kilns. The floor of the kiln



Burning of Sulphur

1. Air Pipes 2. Sulphur Kiln 3. Sulphur 4. Burning Sulphur
5. Molten Sulphur

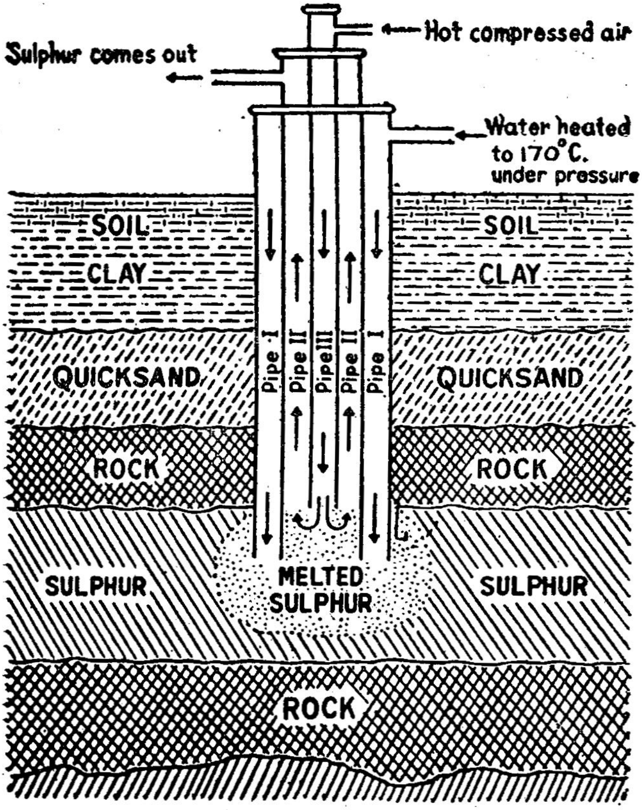
Fig. 26

is sloping. The kiln is provided with vertical pipes in the centre which allows free flow of air inside. The piled ore is lighted and it is allowed to burn.

Sulphur burns at the top and a large amount of heat is produced. Due to this heat, the sulphur inside melts. The molten sulphur flows down the sloping floor. It reaches iron pens. They get solidified in iron pens. This is an impure form of sulphur.

Frasch Process

Large amount of sulphur in the world is obtained from America. It is found deposited in solid form below the surface



Frasch Process
Fig. 27

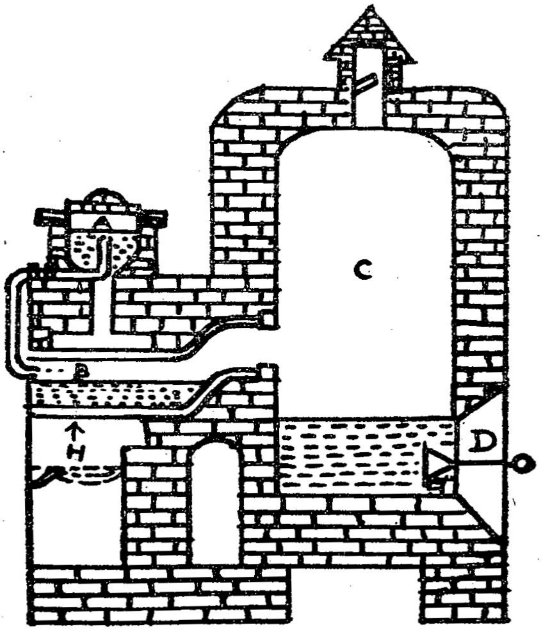
of the earth at a depth of about 250 metres. This is pure sulphur. Three concentric pipes are sunk in the ground till they reach the sulphur bed. Through the outer most pipe, super

heated water (170°C) is sent down under pressure. The melting point of sulphur is about 114°C. The super heated water melts the sulphur in the beds. Hot compressed air is forced through the central pipe.

A foam of molten sulphur mixed with air and water comes out through the middle pipe and reaches the surface. This is collected in large wooden plates and allowed to cool. They get solidified. The sulphur got by this process is 99% pure. This process of extracting sulphur was discovered by **Frasch** in 1903. Hence this is known as **Frasch process.**

Purification of Sulphur

The sulphur extracted from the surface of the soil is impure sulphur. It is taken in iron retorts and heated.



Purification of Sulphur

A. Impure Sulphur *B.* Boiling Sulphur *C,* Brick Chamber *D.* Door *H.* Heat

Fig. 28

Sulphur melts and vapourises. The sulphur vapour is allowed to enter a large chamber made of bricks and is allowed to cool.

At first the vapours condense on the walls of the chamber as a yellow powder called "**flowers of sulphur**" As the walls get heated, the sulphur on the inner walls melts and collects on the floor as a liquid. This is run out through an opening into cylindrical wooden moulds. It gets solidified. Sulphur thus obtained is called roll sulphur.

The Allotropes of Sulphur

The same element exists in different forms with differences in their physical properties. But they have the same chemical properties. This property of elements existing in different forms is known as Allotropy The various forms of the element are known as Allotropes.

Examples :

Elements	Allotropes
Phosphorous	Red phosphorous, White phosphorous
Carbon	Graphite, Coal, Diamond
Sulphur	Rhombic sulphur, Monoclinic sulphur and Plastic sulphur

The Allotropes of Sulphur and Their Properties

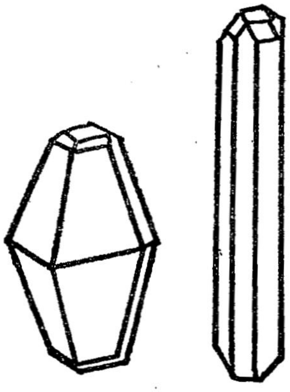
Sulphur exists in several allotropic forms. The important allotropes of sulphur are rhombic sulphur, monoclinic sulphur and plastic sulphur.

Rhombic Sulphur

Dissolve powdered roll sulphur in carbon-di-sulphide. Pour the solution in a watch glass. Allow it to evaporate in air. Carbon-di-sulphide evaporates, rhombic sulphur will be left behind in the watch glass. The rhombic form can be clearly seen through a compound microscope or a powerful convex lens.

Properties

Rhombic sulphur is a pale yellow crystalline solid. Its relative density is 2·1. Its melting point is 112·8°C. This is the most stable form of sulphur. This dissolves in carbon-di-sulphide.



1. Rhombic Sulphur 2. Monoclinic Sulphur
Allotropes of Sulphur
Fig. 29-30

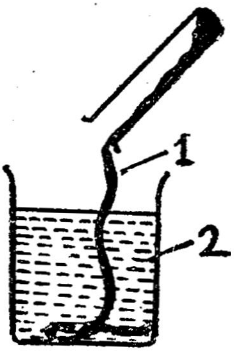
Monoclinic Sulphur

This is also called **prismatic sulphur.** Take roll sulphur in a procelain crucible. Heat the crucible till the sulphur melts. Now stop heating it and allow the crucible to cool. A crust is formed on the surface of the molten sulphur. Pierce the crust in two places with an iron needle and pour the molten liquid sulphur into a beaker. Observe the inner walls of the crucible with the help of a lens. You will find long beautiful needle shaped yellow crystals in the crucible. This is called **monoclinic** sulphur.

This is more yellowish than the rhombic sulphur. It has a relative density of 1·96. It melts at 119°C. It dissolves in carbon–di–sulphide. After a few days it turns into rhombic sulphur.

Plastic Sulphur

Take some powdered roll sulphur in a thick walled test tube and heat it till it boils. Pour this molten sulphur in to cold water, in a beaker. Sulphur gets cooled suddenly and plastic sulphur is formed. This is elastic like rubber. The relative density of plastic sulphur is 1·92. It does not dissolve in carbon-di-sulphide. In course of time, this changes into rhombic sulphur.



Preparation of Plastic Sulphur
1. Molten Sulphur
2. Water
Fig. 31

The following tabular column shows the differences in the physical properties of the allotropic forms of sulphur :

Sl. No.	Properties	Rhombic Sulphur	Monoclinic Sulphur	Plastic Sulphur
1.	Colour	Pale yellow	Bright yellow	Brown
2.	Shape	Rhombic Crystal	Needle shapped Crystal	No Shape
3.	Relative Density	2·06	1·96	1·92
4.	Melting Point	112·8° C	119° C	No definite melting point
5.	Solubility in Carbon-di-sulphide	Soluble	Soluble	Insoluble
6.	Stability	Most Stable	Least Stable becomes rohmbic sulphur after sometime	Least stable becomes rhombic sulphur after sometime

Even though the three forms of sulphur differ in their shapes and physical properties, they are made up of atoms of the same element. We can prove this statement by the following experiments :

Experiment 1

Take equal weights of the three allotropes and burn them individually in air. We get equal weights of sulphur-di-oxide in each case.

$$S + O_2 \rightarrow SO_2 \uparrow$$

Experiment 2

Take the three allotropes separately in three different test tubes. Pour equal amounts of concentrated nitric acid in each test tube and heat them under the same conditions. All the three allotropes give the same product, namely sulphuric acid.

Experiment 3

All the three allotropes of sulphur are convertible into one another.

Effect of Heat on Sulphur

Take some sulphur powder in a test tube and heat it. It melts at 115°*C* and forms a yellow liquid. On further heating, at 162°*C* it becomes orange red and viscous. At this stage, even if the test tube is tilted, it does not spill out. On further heating, at 180°*C*, the viscosity of sulphur increases. It becomes dark brown and then black. At 260°*C*, sulphur melts again and becomes liquid. At 414°*C*, the liquid sulphur boils, giving off reddish orange coloured vapours. On cooling the boiling sulphur, these changes take place in the reverse order and in the end the yellow solid sulphur is again obtained.

Physical Properties of Sulphur

Sulphur is a yellow solid. It is a non-metal. It does not dissolve in water, but dissolves in carbon-di-sulphide and benzene.

Chemical Properties of Sulphur

1. Sulphur burns in air with a blue of flame forming sulphur-di-oxide.

$$S + O_2 \rightarrow SO_2 \uparrow$$

2. When hydrogen is passed through boiling sulphur, hydrogen sulphide is formed.

$$H_2 + S \rightarrow H_2S \uparrow$$

3. When the vapours of sulphur are passed over red hot carbon, carbon-di-sulphide is formed.

$$C + 2S \rightarrow CS_2$$

4. **Action with Metals**

Metals like iron, copper etc., on being heated with sulphur give their sulphides.

$$Fe + S \rightarrow FeS$$

$$Cu + S \rightarrow CuS$$

5. Action with Acids

Hot concentrated nitric acid oxidises sulphur to sulphuric acid.

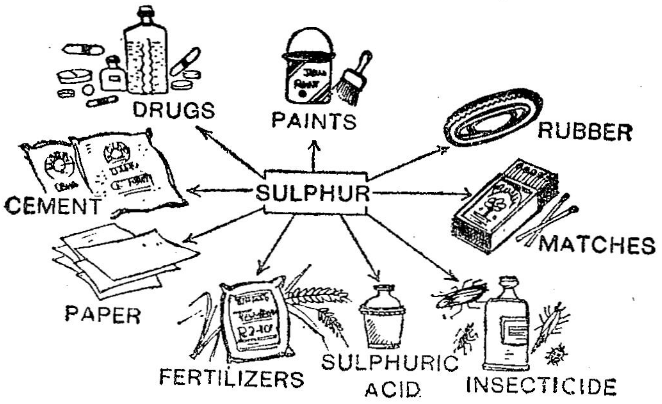
$$S + 6\,HNO_3 \rightarrow H_2SO_4 + 6\,NO_2 \uparrow + 2H_2O$$

6. When mercury and sulphur are ground well in a mortar, mercury loses its lustre and combines with sulphur and black mercuric sulphide is formed.

$$Hg + S \rightarrow HgS$$

Uses of Sulphur

1. Sulphur is used in the preparation of sulpha drugs.
2. It is used for preparing carbon-di-sulphide, gun powder, crackers and sulphuric acid.
3. It is used in the manufacture of matches.
4. Sulphur is used in the preparation of dyes.



Uses of Sulphur
Fig. 31-A

5. It is used in the preparation of sodium-thio-sulphate, calcium sulphite etc.

6. Sulphur-di-oxide which is formed by burning sulphur in air is used as an insecticide.

7. Sulphur is used in the manufacture of fertilizers.

8. Sulphur ointment is used as a medicine for skin diseases like skin eruptions.

9. Sulphur is used for preparing sulphur-di-oxide, sulphur-tri-oxide and sulphuric acid.

10. Sulphur combines with rubber to give ebonite and vulcanite. They are used in the manufacture of fountain pens and motor tyres.

Questions

1. Mention the places where sulphur is found in the free state.
2. Mention some minerals of sulphur.
3. How will you get roll sulphur from volcanic regions?
4. Describe the Sicilian process of extracting sulphur.
5. How is sulphur obtained by Frasch process? Draw the diagram.
6. How is sulphur purified?
7. Explain the changes that take place when sulphur is heated.
8. State the physical and chemical properties of sulphur.
9. What is allotropy?
10. What are the allotropic forms of sulphur?
11. Describe the methods of preparing the allotropic forms of sulphur.
12. How will you prove that all the allotropic forms of sulphur are essentially the same.
13. Compare the properties of the allotropic forms of sulphur.
14. Mention the uses of sulphur.

15. Name the two liquids that dissolve sulphur.

16. What happens when sulphur burns in air?

Know Yourself

In 1839, **Charles Good Year** by mistake spilt sulphur-rubber mixture in the furnace. This mixture was found to be more elastic than the orignial rubber. It was unaffected by heat. Thus he was able to discover **vulcanisation of rubber** by accident.

11. HYDROGEN SULPHIDE

Molecular Formula : H_2S **Molecular Weight : 34**

The two elements hydrogen and sulphur combine to give a compound namely Hydrogen sulphide. A small quantity of this is found in mineral waters and also in the atmosphere. When organic compounds containing sulphur decay hydrogen sulphide is produced. Hence, a foul odour is felt. The molecular formula of hydrogen sulphide resembles that of water (H_2O, H_2S). In the periodic classification of elements both the elements find their place in the VI group.

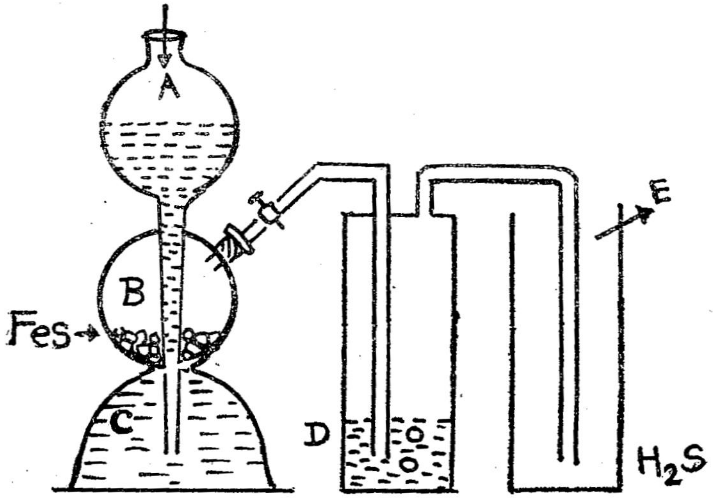
Preparation of Hydrogen Sulphide in the Laboratory

Dilute hydrochloric acid reacts with iron (II) sulphide (FeS) to produce hydrogen sulphide (H_2S) gas. This reaction is made use of to prepare hydrogen sulphide in the laboratory using Kipp's apparatus.

In the laboratory, in order to get a continuous supply of hydrogen sulphide, it is prepared in the Kipp's apparatus. The following experiment shows how it is prepared in the laboratory:

Cylindrical pieces of iron (II) sulphide are placed in the middle bulb of the Kipp's apparatus. Dilute hydrochloric acid is poured through the top bulb. Now the stopper in the middle bulb is opened. The hydrochloric acid comes into contact

with the iron (II) sulphide and reaction takes place and the gas comes out through the outlet in the middle bulb.



Preparation of Hydrogen Sulphide using Kipp's Apparatus
A. Top Bulb B. Middle Bulb C. Bottom Bulb D. Sulphuric acid E. Air
Fig. 32

If the supply of the gas is not required, the stopper in the middle bulb is closed. The acid in the middle bulb goes to the bottom flask (bulb) only. The iron (II) sulphide and the acid are no more in contact and hence there is no reaction.

$$FeS + 2\,HCl \rightarrow FeCl_2 + H_2S \uparrow$$

The hydrogen sulphide gas coming out of the Kipp's apparatus escapes through the stop cock and flows through the delivery tube. The outer end of the delivery tube is placed in a gas jar. The gas is collected in the gas jar by the upward displacement of air, since it is heavier than air.

Conditions for using the Kipp's Apparatus

1. One of the reactants, in a chemical reaction, should be a solid in the form of lumps.

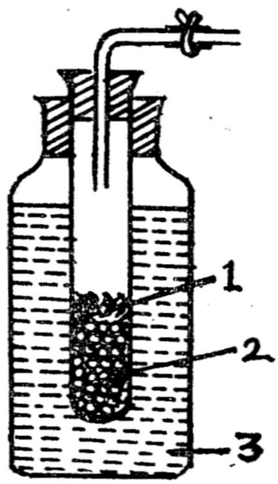
2. The chemical reaction should take place at the room temperature.

3. The resultant product should be a gas.

If there is no proper kipp's apparatus in the laboratory, a simpler improvised apparatus working on the same principles can be made and used. The method of improvising the apparatus is explained below.

Preparation of Hydrogen Sulphide – A Simple Method

Take a wide mouthed bottle of 500 ml. capacity and close it tightly with a wide one holed rubber stopper. Insert a thick walled test tube in the middle of the stopper. The test tube has tiny holes at its bottom. Fill half of the tube with small glass marbles or tiny pebbles. Put some cyclindrical pieces of iron (II) sulphide into the test tube above the glass marbles. The test tube is closed with a one-holed rubber stopper. Insert a delivery tube through the hole. This is connected to another glass tube by a rubber tubing. There is a pinch cock in the middle of the rubber tubing. Now lift the wide stopper and add dilute hydrochloric acid into the bottle to three fourths of its volume, close it tightly with the stopper with the test tube inserted in it.



1. Iron (II) Sulphide 2. Glass marbles 3. Dilute Hydrochloric acid

Fig. 33

If the pinch cock is loosened, hydrochloric acid enters the test tube through the bottom holes and reacts with iron (II) sulphide. Hydrogen sulphide gas is liberated. When the gas is not required, the pinch cock is to be tightened. Due to the pressure of the gas formed inside the tube, hydrochloric acid is pushed down back into the bottle. Hence the contact between hydrochlolric acid and iron (II) sulphide is not now possible. So the reaction stops.

The Test for the Gas

The gas is very easily identified by its odour of rotten eggs. It forms a black shiny precipitate on a filter paper dipped in lead acetate solution.

$$(CH_3\,COO)_2\,Pb + H_2S \rightarrow \underset{(black)}{PbS} \downarrow + 2\,CH_3\,COOH$$

This reaction is used to identify the gas.

Physical Properties of the Gas:

Hydrogen sulphide is a colourless gas with the odour of rotten eggs. The gas dissolves a little in cold water. The solution has the smell of the gas. The gas can be expelled from the solution by boiling it. The gas is poisonous. It is heavier than air. When the gas is cooled, it condenses into a colourless liquid at—60·2°*C*. When it is further cooled, it becomes a transparent glass like solid at —83°*C*.

Chemical Properties

Combustion

Hydrogen sulphide does not support combustion. Introduce a glowing splinter in a jar of the gas. It is put out. The gas burns in air with a pale blue flame. Sulphur is deposited on the inner sides of the gas jar.

$$2\,H_2S + O_2 \rightarrow 2\,H_2O + S \downarrow$$

This reaction shows that hydrogen sulphide contains hydrogen and sulphur.

Acidic Property

Hydrogen sulphide dissolves in water and the solution turns blue litmus red. Hence the gas is acidic. The solution is called **Hydro sulphuric acid.**

Action with Metallic Salts

Pass hydrogen sulphide separately through the solutions of copper sulphate, lead nitrate and antimony chloride. Hydrogen sulphide reacts with the metallic salts and forms

cupric sulphide (black precipitate) antimony sulphide (orange coloured precipitate) and shiny black precipitate of lead sulphide.

$$CuSO_4 + H_2S \rightarrow CuS \downarrow + H_2SO_4 \text{ (black)}$$
$$2\,SbCl_3 + 3\,H_2S \rightarrow Sb_2S_3 \downarrow + 6\,HCl \text{ (orange)}$$
$$Pb(NO_3)_2 + H_2S \rightarrow PbS \downarrow + 2\,HNO_3 \text{ (black)}$$

As a Reducing Agent

Pass hydrogen sulphide through acidified potassium permanganate solution. Hydrogen sulphide gas reduces the violet coloured acidified potassium permanganate solution into a colourless solution. Hydrogen sulphide is oxidised to sulphur and sulphur is precipitated.

$$2\,KMnO_4 + 3\,H_2SO_4 + 5\,H_2S \rightarrow K_2SO_4 + 2\,MnSO_4 + 8\,H_2O + 5\,S\downarrow$$

Pass hydrogen sulphide through acidified potassium dichromate solution. The gas reduces orange coloured acidified potassium dichromate solution into a green coloured solution. Here also sulphur is precipitated.

$$K_2Cr_2O_7 + 4\,H_2SO_4 + 3\,H_2S \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 7\,H_2O + 3\,S\downarrow$$

The above two reactions show that hydrogen sulphide gas is a reducing agent. Pass hydrogen sulphide gas through chlorine water and bromine water. Hydrogen sulphide reacts with chlorine to form hydrogen chloride and yellow sulphur is precipitated.

$$Cl_2 + H_2S \rightarrow 2\,HCl + S\downarrow$$

In the same way, it reacts with bromine water giving hydrogen bromide. Yellow sulphur is precipitated.

$$Br_2 + H_2S \rightarrow 2\,HBr + S \downarrow$$

Uses of Hydrogen Sulphide

1. **Qualitative Analysis** : Hydrogen sulphide is used as an **analytical reagent.** When hydrogen sulphide is passed through the solutions of metallic salts, certain characteristic colour precipitates are obtained. These precipitates have their own individual and peculiar colour. The solubility of the precipitated metallic sulphides differ from solution to solution. Based on the different colours of the precipitates and on the knowledge of the solubility of each sulphide, we can determine the matallic radical (the metals) of the salts.

For example, if the sulphide is orange coloured, the given salt contains antimony. Shiny black precipitate shows the presence of lead in the salt. White precipitate indicates the presence of zinc. So hydrogen sulphide is freely used in the qualitative analysis experiments.

2. Hydrogen sulphide gas is also used as a powerful reducing agent.

3. Hydrogen sulphide is used in the preparation of different coloured metallic sulphides. These sulphides are used in the manufacture of paints and dyes.

Questions

1. What are the elements found in hydrogen sulphide?
2. Describe how hydrogen sulphide is prepared using Kipp's apparatus. Describe the chemical changes taking place in the process by their chemical reactions. What are the circumstances in which Kipp's apparatus is used?
3. Describe the simple method of preparing hydrogen sulphide with the aid of a diagram.

4. What are the products formed when hydrogen sulphide burns in air?

5. Mention two chemical reactions in which hydrogen sulphide acts as a reducing agent.

6. What happens when hydrogen sulphide is passed through the solutions of the following salts:

   (i) copper sulphate

   (ii) lead nitrate

   (iii) antimony chloride.

7. How will you test for hydrogen sulphide gas ?

8. What are the uses of hydrogen sulphide?

Know Yourself

In order to prepare pure hydrogen sulphide, strong hydrochloric acid is added to antimony (III) sulphide and heated.

$$Sb_2S_3 + 6\,HCl \rightarrow 2\,SbCl_3 + 3\,H_2S \uparrow$$

For Thought

(1) Silver vessels become black when they are exposed to atmospheric air for a long time.

(2) When the contents of the egg are poured into silver plates, they become black. Give reason for this.

12. OXIDES OF SULPHUR

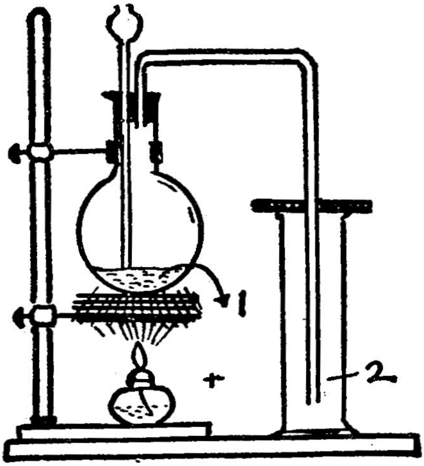
Sulphur-di-Oxide

Molecular Formula : SO_2 **Molecular Weight : 64**

Sulphur-di-oxide is obtained when sulphur is burnt in air. Sulphur-di-oxide, obtained by burning sulphur sticks, was once used to destroy the harmful bacteria inside the rooms of sick persons. In volcanic regions, when cracks are formed on the earth, sulphur-di-oxide will come out.

Preparation of Sulphur-di-oxide in the Laboratory

Take a flat bottomed round flask and put copper turnings in it. Close its mouth tightly by a two-holed rubber stopper.



Preparation of Sulphur-di-oxide
1. Copper turning + Con. Sulphuric Acid 2. Sulphur-di-oxide
Fig. 34

Through one hole pass a thistle funnel. The tip of the funnel should touch the bottom of the flask. Through the other hole a delivery tube is inserted. Keep the outer end of the delivery tube inside a gas jar. Pour concentrated sulphuric acid through the thistle funnel and heat the flask. Copper reacts with concentrated sulphuric acid and sulphur-di-oxide is formed. This gas is heavier than air. It passes through the delivery tube and collects in the gas jar by the upward displacement of air. If dry gas is required, this gas is passed through a wash bottle containing concentrated sulphuric acid and then collected in the gas jar.

$$Cu + 2\ H_2SO_4 \xrightarrow{\Delta} CuSO_4 + 2\ H_2O + SO_2 \uparrow$$

Physical Properties

This is a colourless gas with a suffocating smell. It is poisonous. It is heavier than air. It is soluble in water. The

solution obtained by dissolving sulphur-di-oxide in water is acidic. Sulphur-di-oxide dissolves in water and gives sulphurous acid. Sulphurous acid is unstable. When this gas is subjected to high pressure, it gets converted into liquid.

Chemical Properties

(1) The solution obtained by adding water to the gas jar containing sulphur-di-oxide and on shaking it will turn blue litmus to red. So this gas is acidic in nature.

$$2\,SO_2 + 2\,H_2O \rightarrow 2\,H_2SO_3$$

Hence sulphur-di-oxide is the acid anhydride of sulphurous acid.

(2) When a burning candle is lowered into the gas, it is put out. In addition, the gas does not burn. So this gas is neither combustable nor a supporter of combustion. This gas is a nonsupporter of combustion.

(3) When burning magnesium is introduced into a jar filled with sulphur-di-oxide, it continues to burn. White magnesium oxide is formed. Magnesium sulphide is also formed. In this reaction, sulphur-di-oxide acts as an oxidising agent.

$$3\,Mg + SO_2 \rightarrow 2\,MgO + MgS \downarrow$$

(4) Pour acidified potassium permanganate solution in a jar containing sulphur-di-oxide and shake it well. The violet coloured potassium permanganate solution will change into a colourless solution.

$$2\,KMnO_4 + 5\,SO_2 + 2\,H_2O \rightarrow K_2SO_4 + 2\,MnSO_4 + 2\,H_2SO_4$$

(5) Pour acidified potassium dichromate solution into a jar containing sulphur-di-oxide and shake it well. The orange coloured dichromate solution will turn green.

$$K_2Cr_2O_7 + H_2SO_4 + 3\,SO_2 \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + H_2O$$

These two reactions show that sulphur-di-oxide is a reducing agent.

(6) Put some moist coloured flowers in a jar, filled with sulphur-di-oxide and observe then after some time. The flowers lose their colours. Hence we learn that sulphur-di-oxide works as a bleaching substance. Sulphur-di-oxide combines with the moisture and changes into sulphuric acid and nascent hydrogen is liberated. This nascent hydrogen removes the colour of the flowers by reduction. Substances bleached by sulphur-di-oxide when kept in air absorb the oxygen in the air and attain their original colour after some time. The bleaching action of sulphur-di-oxide is by reduction. Sulphur-di-oxide is not a powerful bleaching substance. It will not destroy the substances bleached by it. Hence sulphur-di-oxide is used to bleach silk and wollen clothes. Compare the bleaching action of chlorine with that of sulphur-di-oxide.

(7) When sulphur-di-oxide is passed through a solution of caustic alkali, the gas is absorbed and sulphites are formed.

$$2\,NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$$

Sulphites are stable unlike sulphurous acid.

Test to identify The Gas

This gas can be identified by its charactersitic odour and by changing the colour of acidified potassium dichromate solution into green.

Uses of Sulphur-di-oxide

1. This gas is largely used to prepare sulphuric acid.
2. It is used to bleach silk fabrics, wool and hay which are destroyed by chlorine.
3. It is used to preserve fruits and as a disinfectant.

4. It is used as an antichlor to remove chlorine from fabrics bleached by chlorine.

5. Liquid sulphur-di-oxide is used in refregirators.

Sulphur-tri-Oxide

Molecular Formula : SO_3 **Molecular Weight : 80.**

This is another oxide of sulphur. A sulphur-di-oxide molecule contains one atom of sulphur and two atoms of oxygen. A sulphur-tri-oxide molecule contains one sulphur atom and three oxygen atoms. Even when sulphur is burnt in excess of oxygen, only sulphur-di-oxide is formed. Sulphur-di-oxide combines with oxygen and gives another oxide of sulphur and it is sulphur-tri-oxide. To prepare sulphur-tri-oxide, catalysts are needed. Then only sulphur-di-oxide will combine with oxygen and give sulphur-tri-oxide.

Preparation of Sulphur-tri-oxide

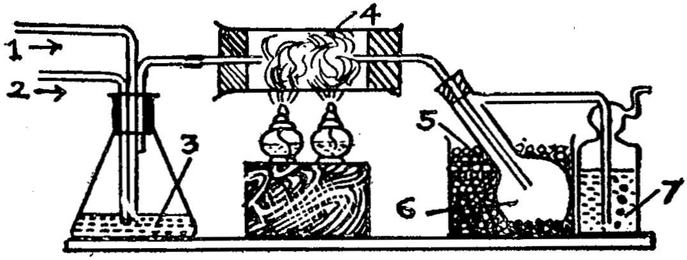


Fig. 35
Preparation of Sulphur-tri-oxide
1. Sulphur-di-oxide Gas 2. Oxygen 3. Con. Sulphuric Acid 4. Platinum asbestos 5. Freezing Mixture 6. Sulphur-tri-oxide crystals, 7. Con. Sulphuric Acid

Set up the apparatus as shown in Fig. 35. When pure and dry sulphur-di-oxide is mixed with pure and dry oxygen and passed over platnised asbestos kept at 450°*C* sulphur-tri-oxide is formed. This sulphur-tri-oxide, when passed into the *U*-tube kept in the freezing mixture it gets cooled and changes into needle shaped crystals. Here platinised asbestos acts as a catalyst.

$$2\,SO_2 + O_2 \xrightarrow{450^\circ C} 2\,SO_3$$

Sulphur-tri-oxide is a liquid at ordinary temperature. It becomes a solid on cooling. Solid sulphur-tri-oxide melts at 16·8°C and boils at 44·8°C. Sulphur-tri-oxide dissolves in water with a hissing noise liberating heat and gives sulphuric acid.

$$SO_3 + H_2O \rightarrow H_2SO_4$$

Properties of Sulphur-tri-oxide

When sulphur tri-oxide-crystals are put in water in a beaker, they dissolve producing a noise. During the formation of the solution, heat is liberated. This solution turns blue litmus into red.

$$SO_3 + H_2O \rightarrow H_2SO_4$$

The solution obtained by dissolving sulphur-tri-oxide in water is sulphuric acid. When sulphur-tri-oxide is directly dissolved in water, large quantities of acid fumes are produced. To avoid this, sulphur-tri-oxide should be dissolved in sulphuric acid. Now fuming sulphuric acid is obtained. This is also known as **Oleum,**.

$$H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$$

By dissolving oleum in water with care, concentrated sulphuric acid is obtained.

$$H_2S_2O_7 + H_2O \rightarrow 2\,H_2SO_4$$

Uses

1. Sulphur-tri-oxide is used extensively in the manufacture of sulphuric acid.

2. It is also used to prepare synthetic dyes.

Questions

1. Mention the two oxides of sulphur and give their molecular formula.
2. What happens when sulphur is burnt in air. Give the equation.
3. Describe the preparation of sulphur-di-oxide in the laboratory.
4. What happens burning magnesium is introduced into a jar containing sulphur-di-oxide?
5. How does sulphur-di-oxide react with water?
6. What happens when sulphur-di-oxide is passed through sodium hydroxide solution?
7. State the uses of sulphur-di-oxide.
8. How will you prepare sulphur-tri-oxide from sulphur-di-oxide?
9. Describe the preparation of sulphur-tri-oxide?
10. How does sulphur-tri-oxide react with water?
11. What is oleum? What is its molecular formula?
12. How is concentrated sulphuric acid prepared from oleum?
13. By what method sulphur-di-oxide bleaches the colour?
14. Give the uses of sulphur-tri-oxide.
15. Explain the bleaching action of sulphur-di-oxide.

13. SULPHURIC ACID (HYDROGEN SULPHATE)

Molecular Formula : H_2SO_4; **Molecular Weight :** 98.

Sulphuric acid is the first and foremost of all the chemicals. There is hardly any industry which does not use sulphuric acid. The amount of sulphuric acid used is a measure of the progress of a country. Further, other acids like hydrocloric acid and nitric acid are prepared using sulphuric acid, which is chemically known as **hydrogen sulphate.** It is used in laboratories and in the factories to manufacture innumberable chemicals. So it is called **King of Chemicals.**

In the year 1648, **Glauber** prepared sulphuric acid by the distillation of iron (II) sulphate known as **Green Vitriol.** So, sulphuric acid is also known as **'Oil of Vitriol'.** Since oxygen is one of the constituent elements of this acid, Sulphuric acid is an **oxy-acid.** Its chemical name is **hydrogen sulphate.**

Hydrogen, sulphur and oxygen are the constituent elements of this acid. It is not commonly prepared in the laboratories. The acid is commercially manufactured by two processes : 1. **Contact process,,** 2. **Lead Chamber process.** In modern days, lead chamber process is not widely used. Large quantities of sulphuric acid are produced by contact process only.

In both the processes, sulphur-di-oxide is first prepared. Then sulphur-di-oxide is made to combine with oxygen with the help of a catalyst to get sulphur-tri-oxide. Sulphur-tri-oxide is dissolved in water to from sulphuric acid.

Preparation of Sulphuric Acid using Contact Process

There are three steps in this process. First sulphur-di-oxide is prepared.

(1) **Iron pyrites or sulphur is burnt in air to get sulphur-di-oxide.**

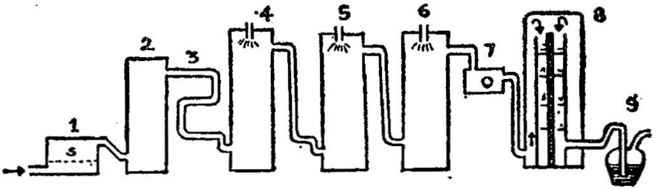
$$S + O_2 \rightarrow SO_2$$
$$4\,FeS_2 + 11O_2 \rightarrow 2\,Fe_2O_3 + 8\,SO_2 \uparrow$$

(2) **Next sulphur-di-oxide is converted into sulphur-tri-oxide.**

$$2\,SO_2 + O_2 \rightarrow 2\,SO_3$$

Sulphur-di-oxide should be purified before the reaction takes place to form sulphur-tri-oxide. Impurities such as sulphur particles and arsenic (III) oxide should be removed from the gas. If the above impurities are present in the gas, the catalyst which converts sulphur-di-oxide into sulphur-tri-oxide can not function efficiently. Impurities poison the catalyst and make

it ineffective. Sulphur–di–oxide is mixed with excess of air and the mixture is passed through a purifying tower. Gushing



Manufacture of sulphuric Acid by Contact Process

1. Burner 2. Purifying Tower 3. Cooling Coil 4. Scrubbing Tower 5. Drying Tower 6. Arsenic Purifier 7. Testing Box 8. Contact Chamber 9. Absorption of Sulphuric Acid.

Fig. 36

steam from the top of the tower washes sulphur–di–oxide. Most of the impurities and dust settle down. The gases are now dust free. Purified mixture of sulphur–di–oxide and air is passed through the bottom of another tower. This is known as scrubbing tower. Water pours in torrents from the top of this tower.

The pouring water removes further impurities. The mixture is dried by passing it through a drying tower. Concentrated sulphuric acid drips from the top of the drying tower. The dried gas mixture is passed through a chamber which removes arsenic oxide. This tower is known as arsenic purifier. Here the arsenic impurities are removed. The purity of the gas mixture is tested by sending them into an illuminated box with glass sides. If the gases are pure, they will be optically clear in the testing box. The pure and dry gases are then led into a contact chamber.

Chemical Changes in the Contact Chamber : The catalyst vanadium–pentoxide is kept in porous tubes in the contact chamber. The temperature of the chamber is between 400° *C.* - 450° *C.* Chemical combination takes place between air and sulphur-di-oxide in the presence of the catalyst in the contact chamber. Sulphur–di–oxide combines with oxygen to form sulphur–tri–oxide.

$$2\,SO_2 + O_2 \rightarrow 2\,SO_3 \uparrow$$

Heating should be stopped as soon as the chemical reaction starts, because the reaction which gives sulphur-tri-oxide is an **exothermic reaction.**

(3) After sulphur-di-oxide is fully converted into sulphur-tri-oxide, the sulphur-tri-oxide gas is passed through an absorbing tower from the top of which concentrated sulphuric acid is allowed to fall in drops. Sulphur-tri-oxide is absorbed by concentrated sulphuric acid to give **oleum or fuming sulphuric acid.**

$$H_2SO_4 + SO_3 \rightarrow H_2S_2O_7$$

Fuming sulphuric acid is dissolved in the requisite quantity of water to get concentrated sulphuric acid of any desired strength.

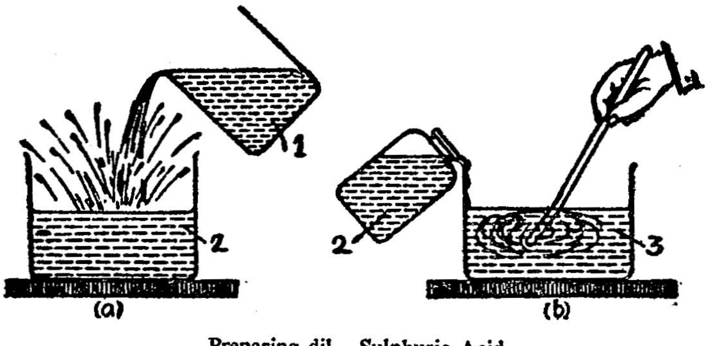
$$H_2S_2O_7 + H_2O \rightarrow 2\,H_2SO_4$$

The sulphuric acid obtained by contact process is pure and concentrated.

Preparation of Dilute Sulphuric Acid

Experiment

Dilute sulphuric acid is used to conduct many experiments



Preparing dil. Sulphuric Acid
(a) Wrong Procedure (b) Right Procedure
(1) Water (2) Con. sulphuric Acid (3) Water.
Fig. 37

in the laboratories. Water should not be added to concentrated sulphuric acid in order to get dilute sulphuric acid. This is

because when water is added to concentrated sulphuric acid, a lot of heat is produced and water becomes steam. Further sulphuric acid spurting out is likely to cause serious burn injuries on the skin, face or the eye. So water should not be added to concentrated sulphuric acid in order to get dilute sulphuric acid.

To prepare dilute sulphuric acid, water is taken in a wide beaker, and the concentrated sulphuric acid is allowed to pass through the inside wall of the beaker, little by little. Meanwhile the mixture in the beaker is stirred continuously by means of a glass rod as shown in Fig. 37. Heat is produced slowly. The spurting of the acid is prevented.

Physical properties

Sulphuric acid is a colourless, oily liquid. Its relative density is 1·84. It readily absorbs moisture from the atmosphere.

Affinity for Water

Experiment 1

Take concentrated sulphuric acid in a test tube and slowly drop a blue copper (II) sulphate crystal. Copper (II) sulphate loses water and becomes a white powdery substance. Concentrated sulphuric acid removes water from the crystal and so the crystal loses its blue colour and becomes white. **This is known as anhydrous copper sulphate.**

Experiment 2

Take a small quantity of powdered cane sugar in a porcelain cup and add three of four drops of concentrated sulphuric acid to the sugar. The white sugar turns black. Sugar contains carbon, hydrogen and oxygen. The water forming elements, hydrogen and oxygen are absorbed by the concentrated sulphuric acid. Carbon is set free hence cane sugar turns black.

Experiment 3

Take some saw dust in a porcelain cup. Add concentrated sulphuric acid to the dust. The saw dust becomes black. As

in the above case, hydrogen and oxygen are removed by the sulphuric acid from the saw dust. Carbon is set free.

The above experiments show the strong affinity of concentrated sulphuric acid for water.

Reactions of Dilute Sulphuric Acid with Metals

Take zinc, magnesium, aluminium and iron in separate test tubes and add dilute sulphuric acid to each metal. All the metals react with the dilute sulphuric acid and displace hydrogen from it.

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2 \uparrow$$
$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2 \uparrow$$
$$2\,Al + 3\,H_2SO_4 \rightarrow Al_2\,(SO_4)_3 + 3\,H_2 \uparrow$$

Reactions of hot concentrated Sulphuric Acid with Metals

Take zinc, copper and iron in separate test tubes. Add concentrated sulphuric acid to each metal. Heat the test tubes. Metals react with concentrated sulphuric acid to liberate sulphur-di-oxide.

$$Cu + 2\,H_2SO_4 \rightarrow CuSO_4 + 2\,H_2O + SO_2 \uparrow$$
$$Zn + 2\,H_2SO_4 \rightarrow ZnSO_4 + 2\,H_2O + SO_2 \uparrow$$

Experiment 1

Take sodium nitrate in a test tube. Add some concentrated sulphuric acid to it. Heat the contents. Nitric acid vapours come out of the test tube.

$$NaNO_3 + H_2SO_4 \rightarrow NaHSO_4 + HNO_3$$

Experiment 2

Take some sodium chloride salt in a test tube. Add some concentrated sulphuric acid and heat the mixture. Hydrogen chloride gas comes out. It fumes in the moist air.

$$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl \uparrow$$

Test for Sulphuric Acid

When sulphuric acid is added to barium chloride solution, a dense white precipitate called barium sulphate is formed. This white precipitate does not dissolve in water and in acids.

$$BaCl_2 + H_2SO_4 \rightarrow BaSO_4 \downarrow + 2\ HCl$$

Uses of Sulphuric Acid

1. Sulphuric acid is used to manufacture hydrochloric acid and nitric acid on a large scale.

2. It is used in the making of fertilizers like ammonium sulphate and super phosphate.

3. It is used in strorage cells and other ordinary cells.

4. It is used to dry gases. It is used in the dessicators.

5. It is used in the laboratory to prepare gases like hydrogen, sulphur-di-oxide etc.

6. It is used in the refining of petroleum.

7. It is used in the production of explosives like *T. N. T.* and nitroglycerine.

8. Ether, dyes and many medicines are prepared using sulphuric acid.

Sulphates

Salts obtained from sulphuric acid are called sulphates. In each molecule of sulphuric acid, there are two displaceable hydrogen atoms (displaced by metals). So sulphuric acid is a dibasic acid. Hence two types of salts namely sulphates and bi-sulphates are obtained from sulphuric acid.

Sulphates are obtained by the action of sulphuric acid on metals, their oxides, their hydroxides and their carbonates.

$$Zn + 2\ H_2SO_4 \rightarrow ZnSO_4 + 2\ H_2O + SO_2 \uparrow$$
$$2\ KOH + H_2SO_4 \rightarrow K_2SO_4 + 2\ H_2O$$
$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$
$$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2O + CO_2 \uparrow$$

Sulphates are generally crystalline in shape. Some crystalline sulphates have water molecules in the form of **water of hydration.** On being heated, the sulphate crystals give out the water of hydration. When the crystals lose their water of hydration, they lose their crystalline shapes too. Coloured sulphates lose their colour. Sulphates are generally soluble in water except barium sulphate, calcium sulphate and lead sulphate.

Alums

When a mixture of potassium sulphate or sodium sulphate or ammonium sulphate is dissolved in water and the solution is concentrated and cooled, then a double salt separates in the form of crystals. These csystals are hydrated and have large amount of water of hydration in their composition. These double salts of similiar composition are called Alums.

Potash Alum

Its chemical name is potassium aluminium double sulphate. Each of its molecules contain 24 water molecules in the form of water of hydration. The molecular formula of potash alum is $[K_2SO_4Al_2\ (SO_4)_3.\ 24\ H_2O]$

Preparation of Potash Alum

Take 30 gm. of aluminium sulphate $[Al_2\ (SO_4)_2\ 18H_2O]$ in a beaker. Add 8 gm. of potassium sulphate (K_2SO_4) to it. Pour hot water into the beaker little by little and dissolve the salt mixture in it. Filter the solution and pour the clean solution into a wide beaker. Keep the beaker undisturbed in a dust free atmosphere and in a still place. Let the solution evaporate slowly. The crystals of potash alum are formed after a few days.

Properties

Potash alum crystals are octahedral. They can be made to grow bigger and bigger in size by suspending a small crystal in its saturated solution.

Uses

(1) Potash alum is used as a **mordant** in dyeing.

(2) It is used to stop bleeding from small cuts.

(2) It is used to prevent diseases of the gums.

(4) It is used for 'sizing' paper and for tanning leather.

(5) It is used to get **clear water** since it helps the dust particle in the water to settle at the bottom.

Ammonium Sulphate [$(NH_4)_2 SO_4$]

Every year, throughout the world, about **10 million tons** of this important chemical fertilizer is produced. In order to manufacture this fertilizer on a large scale, ammonia, carbon-di-oxide are dissolved largely in water and calcium sulphate is added. First ammonium carbonate is formed. The ammonium carbonate reacts with calcium sulphate forming ammonium sulphate and calcium carbonate by double decomposition. Ammonium sulphate is formed in solution and calcium carbonate is precipitated. Hence ammonium sulphate can easily be separated.

$$2\,NH_3 + CO_2 + H_2O \rightarrow (NH_4)_2CO_3$$
$$CaSO_4 + (NH_4)_2CO_3 \rightarrow CaCO_3 \downarrow + (NH_4)_2SO_4$$

Properties

This is a crystalline substance. This is white in colour It is soluble in water.

Uses of Ammonium Sulphate

1. This is used as a good fertilizer.
2. This is used to prepare the other ammonium salts.
3. This is also used to make fire-proof (fire resistant) clothes.

Copper (II) Sulphate [$Cu(SO_4) \cdot 5\,H_2O$]

In each molecule of copper (II) sulphate, there are five molecules of water in the form of **water of hydration**. This is also known as **'Blue Vitriol'**. This is a crystalline solid, deep blue in colour. This contains the water of hydration. It dissolves in water. This is prepared by the action of dilute sulphuric acid on copper (II) oxide or copper carbonate.

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$
$$CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2 \uparrow$$

When copper (II) sulphate is heated, it loses the water of hydration. It also loses its colour and crystalline shape. It becomes white powder. When it is exposed to air, it absorbs moisture from the atmosphere and regains its crystal shape with its colour.

Uses of Copper (II) Sulphate

(1) It is used as a depolarizer in the Daniel cell.

(2) It is used as the electrolyte in **copper voltameter.**

(3) **Bordeaux** mixture, a solution containing copper (II) sulphate and dilute calcium hydroxide is used as an **insecticide.**

(4) This is used as a mordant in dyeing.

(5) Copper sulphate is added to wood pulp to make the paper free from the attack of white ants.

(6) Copper sulphate is used in tanning leather.

Magnesium Sulphate $[Mg\ (SO_4)\cdot 7\ H_2O]$

This is also called as **Epsom salt** since this salt is obtained in plenty in the lake in the district of **Epsom** in England. This is obtained as a result of the reaction of magnesium metal with dilute sulphuric acid. During the reaction, hydrogen is displaced from the acid.

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2 \uparrow$$

Properties of Magnesium Sulphate

This is also a crystalline solid having the water of hydration. On being heated, it loses not only the water molecules but also its shape. This is soluble in water and the solution is bitter to taste.

Uses

(1) It is used as a laxative, and as a **mordant in the dyeing industry.**

(2) It is used in **tanning** and also in the manufacture of **fireproof** cloth and bricks.

(3) A weak solution of this sulphate is used for medicinal purposes.

Calcium Sulphate [$CaSO_4 . 2H_2O$]

This occurs in nature as deposits under the earth in some places. It is also known as **Gypsum.** This is produced in the laboratory by the action of dilute sulphuric acid on calcium oxide. During the reaction, calcium sulphate and water are formed.

Properties

This sulphate has two molecules of water in each of its molecules as the water of hydration. When heated to 120° *C* it loses half its water of hydration and becomes the substance known as **"Plaster of Paris"** [$CaSO_4 . \frac{1}{2} H_2O$]. When water is added to plaster of paris, it is absorbed and a hardened substance is formed. The resultant product occupies more volume.

Uses of Calcium Sulphate

1. It is used in the preparation of "Plaster of Paris", cement and moulds.

2. It is used in the manufacture of cement.

3. Plaster of paris is used in settling the bones in their proper places after a fracture.

4. It is used in the manufacture of ammonium sulphate, a well known fertilizer.

5. It is used to make black board chalk.

Tests for Sulphates

Take the solution of any sulphate (soluble in water) in a test tube. Add barium chloride solution to it. What do you observe? You see a thick white precipitate being formed which does not dissolve in dilute nitric acid. This is a test for the sulphates.

Repeat this experiment with the solution of different sulphates.

In each experiment we get the same white precipitate. This white precipitate does not dissolve in dilute nitric acid.

Therefore, barium sulphate, obtained in the form of white precipitate by the reaction of sulphates with barium chloride, does not dissolve in dilute nitric acid.

$$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2\,NaCl$$
$$BaCl_2 + MgSO_4 \rightarrow BaSO_4 + MgCl_2$$

Questions

1. Name the two processes of manufacturing sulphuric acid.
2. What is the principle involved in the contact process?
3. How is sulphuric acid manufactured in the contact process?
4. Why should sulphur-di-oxide be purified before producing sulphuric acid in the contact chamber?
5. How is sulphur-tri-oxide converted into sulphuric acid in the contact chamber?
6. What are the physical properties of sulphuric acid?
7. How does dilute sulphuric acid react with metals?
8. How is dilute sulphuric acid prepared?
9. Write the reaction of copper with concentrated sulphuric acid. Give the equation.
10. What are the salts that go to prepare hydrochloric acid and nitric acid?
11. Which is the king of chemicals? Why is it called so?
12. Give two experiments to illustrate the affinity of sulphuric acid for water.
13. Why does copper (II) sulphate lose its colour in concentrated sulphuric acid?

14. What happens when concentrated sulphuric acid is added to sugar? Why?
15. What are the uses of sulphuric acid?
16. What are sulphates?
17. What are alums?
18. Mention the names of some sulphates which do not dissolve in water.
19. How is alum prepared? State its properties and uses.
20. Give the chemical name for alum.
21. Write down the chemical names of the following compounds :

(a) epsom salt. (b) gypsum (c) blue vitriol

For Thought

Sulphuric acid is used in the preparation of other acids. But other acids are not used in the preparation of sulphuric acid.

14. NITROGEN AND ITS OXIDES

Molecular Formula : N_2 **Molecular Weight : 28**

Occurrence

Nitrogen is present in the atmosphere in large quantities, in the free state to the extent of 78% by volume. In plant and animal bodies nitrogen is present as proteins. It is also present in naturally available compounds such as nitre (KNO_3) and chile salt petre ($NaNO_3$). Nitrogen is the basic constituent of proteins which are essential for the growth of living organisms.

Nitrogen from Air

Air is a mixture. Approximately 20% of it by volume is oxygen. The remaining part is almost nitrogen (78%) with very small quantities of other gases. This fact can be understood by the bell-jar experiment. So it is possible to separate nitrogen and oxygen in the air.

Comparatively neglegible quantities of carbon-di-oxide, water vapour and dust particles are removed and then the dry and pure air is a mixture of pure nitrogen and pure oxygen only. This pure air is liquefied. In this liquid air, both

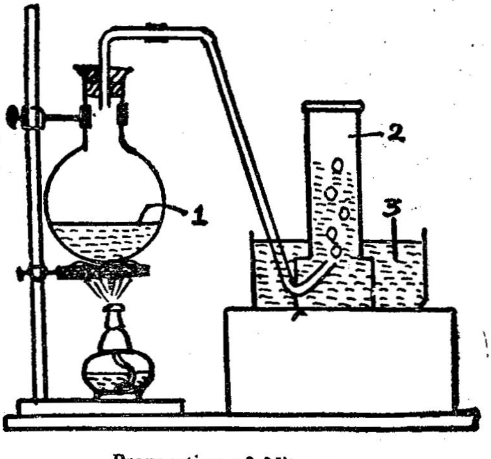
nitrogen and oxygen will be found in the liquid state. The boiling point of liquid nitrogen is—196°*C.* and that of liquid oxygen is—183°*C.* So when this pure liquid air is fractionally distilled, nitrogen whose boiling point is lower, will come out first as vapour. The vapours of nitrogen can be collected separately. Oxygen vapours that come out next, can be collected separately. Thus nitrogen is got from atmospheric air in large quantities.

Laboratory Preparation of Nitrogen

Principle : Ammonium nitrite is not a stable compound. On heating, it easily decomposes and gives off nitrogen. Sometimes when ammonium nitrite is heated, it may explode. So ammonium nitrite is prepared first by double decomposition and then heated. So a mixture of the concentrated solutions of ammonium chloride and sodium nitrite is taken in a flask and heated. These two compounds undergo double decomposition to give ammonium nitrite. This ammonium nitrite decomposes on heating, to give off nitrogen.

Preparation

A mixture of the concentrated solutions of sodium nitrite and ammonium chloride is taken in a flask. The flask is fitted



Preparation of Nitrogen
1. Sodium nitrite + Ammonium chloride 2. Nitrogen 3. Water
Fig. 38

tightly with a one-holed rubber stopper. A delivery tube is passed through a hole. The other end of the tube is kept as shown in Fig. 38. Now the flask is heated carefully. Chemical reaction takes place and nitrogen gas comes out. The outcoming gas passes through the delivery tube and gets collected in the gas jar by the downward displacement of water.

$$NH_4Cl + NaNO_2 \rightarrow NH_4NO_2 + NaCl$$
$$NH_4NO_2 \rightarrow N_2 \uparrow + 2\ H_2O$$

Nitrogen is thus prepared in the pure state.

Physical Properties

Nitrogen is a colourless, odourless, tasteless, non-poisonous gas. It is an inert gas. It is lighter than air and sparingly soluble in water. When cooled below—196°C, it becomes a colourless liquid. At— 210° C, it freezes into a colourless solid.

Chemical Properties

1. Nitrogen does not bring about any change in colour in both the litmus papers. So nitrogen is neither acidic nor basic.

2. It is neither combustible nor supporter of combustion. Hence it is an inert gas.

3. Nitrogen does not easily react with other elements. But at high temperature of over 3000°C. produced by electric arc, it combines with oxygen to give nitrogen (II) oxide. This reaction is made use of to fix the atmospheric nitrogen by arc process.

$$N_2 + O_2 \rightarrow 2\ NO \uparrow$$

4. When a mixture of nitrogen and hydrogen is subjected to very high pressure and passed over a suitable catalyst at 500°C, ammonia is formed. This reaction is made use of in the fixation of atmospheric nitrogen by Haber's process.

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3 \uparrow$$

5. When nitrogen is passed over magnesium or aluminium heated to a very high temperature, metallic nitrides are formed.

$$3\ Mg + N_2 \rightarrow Mg_3N_2$$
$$2\ Al + N_2 \rightarrow 2\ AlN$$

Uses of Nitrogen

1. Nitrogen is useful in the manufacture of ammonia, nitric acid and such other essential nitrogen compounds.

2. As air contains nitrogen, the chemical reaction of oxygen is reduced. So rapid combustion of substances in air is prevented.

3. Nitrogen is used for filling electric bulbs.

4. It is used to create an atmosphere of inertness in the extraction of certain metals.

5. It is used in the industrial manufacture of substances like calcium cyanamide, nitric acid and other nitrogen compounds.

Oxides of Nitrogen

An oxide is a compound of an element with oxygen. At ordinary temperatures, nitrogen is an inactive element. But at high temperatures, nitrogen atoms and oxygen atoms combine in various proportions to give rise to various oxides of nitrogen. Among those oxides of nitrogen, the following are very important:

Oxides	Formula	Molecular Weight
1. Nitrogen (I) oxide	N_2O	44
2. Nitrogen (II) oxide	NO	30
3. Nitrogen (III) oxide	N_2O_3	76
4. Nitrogen (IV) oxide	NO_2	46
5. Nitrogen (V) oxide	N_2O_5	108

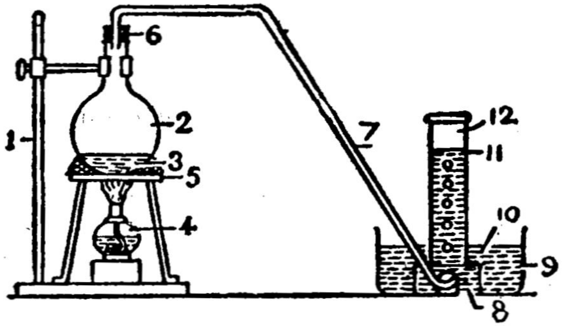
Nitrogen (I) Oxide

Molecular Formula : N_2O **Molecular Weight : 44**

A molecule of this nitrogen (I) oxide contains two nitrogen atoms and one oxygen atom. This gas is also known as "**laughing gas**" because when this gas is excessively inhaled, it makes us laugh. A scientist by name **Priestly** first prepared this gas.

Preparation of Nitrogen (I) Oxide

Some ammonium nitrate crystals are taken in a flask. The flask is fitted with a one-holed rubber stopper. Through the hole a delivery tube is passed. The other end of the tube is



Preparation of Nitrogen (I) Oxide
1. Stand 2. Flask 3. Ammonium Nitrate 4. Spirit Lamp 5. Wire Gauze 6. Cork 7. Delivery Tube 8. Bee-hive Shelf 9. Trough 10. Water 11. Gas Jar 12. Nitrogen (I) Oxide.
Fig. 39

kept connected to a bee-hive shelf kept under hot water. On the bee-hive shelf, an inverted gas jar filled with hot water is placed. The flask is heated carefully. Ammonium nitrate decomposes and gives nitrogen (I) oxide and steam. Steam condenses and gets deposited as water drops on the walls of the flask. Nitrogen (I) oxide passes through the delivery tube and gets collected in the gas jar by the downward displacement of hot water. Since nitrogen (I) oxide is soluble in cold water, hot water is used.

$$NH_4NO_3 \xrightarrow{\Delta} 2H_2O + N_2O \uparrow$$

Precaution

When the temperature exceeds 250°C, nitrogen (I) oxide will come out in very large quantities and this may lead to the explosion of the flask. So heating of ammonium nitrate should be done uniformly, gradually and carefully. About 200° C. would be the optimum temperature for a continuous and steady liberation of nitrogen (I) oxide.

Physical Properties

1. It is a colourless gas, heavier than air with a faint sweet odour.

2. It dissolves in cold water. It does not dissolve to such an extent in warm water. It dissolves more in alcohol than in water.

3. When nitrogen (I) oxide is inhaled, it causes excitement and makes the person laugh. Excess inhaling of the gas will make the person unconscious and sometimes it may prove fatal too.

Chemical Properties

1. This is a neutral oxide. It is neither acidic nor basic.

2. When a glowing splinter is introduced into a jar of nitrogen (I) oxide, the splinter burns brightly. Nitrogen and oxygen are produced.

$$2\,N_2O \xrightarrow{\Delta} 2\,N_2 \uparrow + O_2 \uparrow$$

3. Elements such as burning magnesium, phosphorus and sulphur continue to burn with more brightness in this gas and get converted into their respective oxides. Nitrogen is liberated in the reaction. So this gas is an 'oxidising agent'.

$$N_2O + Mg \rightarrow MgO + N_2$$
$$2\,N_2O + S \rightarrow SO_2 + 2\,N_2$$
$$2\,P + 5\,N_2O \rightarrow P_2O_5 + 5\,N_2$$

4. When nitrogen (I) oxide is passed over heated copper turnings, it gets reduced to nitrogen.

$$N_2O + Cu \rightarrow N_2 \uparrow + CuO$$

Uses

Nitrogen (I) oxide mixed with oxygen was used as an anesthetic in surgery by dentists.

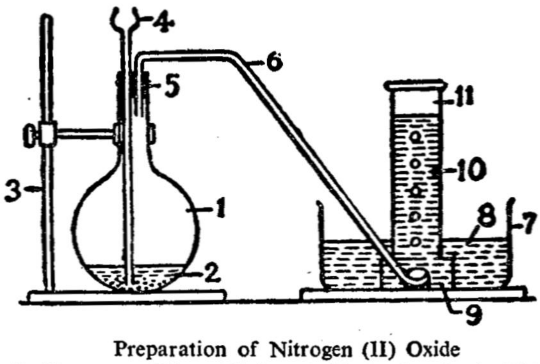
Nitrogen (II) Oxide

Molecular Formula : NO **Molecular Weight : 30**

In a molecule of nitrogen (II) oxide, one atom of nitrogen and one atom of oxygen are present. It was **Priestly** who found out that this is a compound and explained its properties.

Preparation of Nitrogen (II) Oxide

Copper turnings are taken in a flat-bottomed flask fitted with a two-holed rubber stopper. Through one hole a thistle



Preparation of Nitrogen (II) Oxide
1. Flask 2. Copper + Dilute Nitric Acid 3. Stand 4. Thistle Funnel 5. Cork 6. Delivery Tube 7. Trough 8. Water 9. Bee-hive Shelf 10. Gas Jar 11. Nitrogen (II) Oxide

Fig. 40.

funnel is inserted with its other end touching the bottom of the flask. Through the other hole, passes a delivery tube as shown in Fig. 40. The free end of the tube ends in the bee-hive shelf, which in kept under water in a trough. A gas jar filled with water is kept inverted over the bee-hive shelf Now dilute nitric acid (1 part by volume of strong nitric acid

mixed with an equal volume of water) is poured into the flask through the thistle funnel. Copper reacts with the acid and colourless nitrogen (II) oxide is liberated. It is collected in the jar by the downward displacement of water.

$$3\,Cu + 8\,HNO_3 \rightarrow 3\,Cu\,(NO_3)_2 + 2\,NO\uparrow + 4\,H_2O$$

Physical Properties

This is a colourless, odourless gas, slightly heavier than air. It is sparingly soluble in water.

Chemical Properties

1. This is a neutral oxide, neither acidic nor basic.

2. When nitrogen (II) oxide is exposed to air, it easily combines with the oxygen in the air to form red brown nitrogen (IV) oxide.

3. At a very high temperature (above 1000°C,) it decomposes into nitrogen and oxygen.

$$2\,NO \xrightarrow{\Delta} N_2\uparrow + O_2\uparrow$$

4. Burning candle when introduced into a jar of nitrogen (II) oxide is put out. But vigorously burning magnesium and phosphorous continue to burn in this gas forming their respective oxides.

$$2\,Mg + 2\,NO \rightarrow 2\,MgO + N_2$$
$$4\,P + 10\,NO \rightarrow 2\,P_2O_5 + 5\,N_2$$

5. Nitrogen (II) oxide is readily absorbed by a strong solution of iron (II) sulphate (ferrous sulphate) to give rise to a dark brown solution.

$$FeSO_4 + NO \rightarrow FeSO_4\cdot NO$$

On heating the brown solution, nitrogen (II) oxide is again liberated.

6. When nitrogen (II) oxide is passed over heated copper, the gas is reduced to nitrogen.

$$2\,Cu + 2\,NO \rightarrow 2\,CuO + N_2 \uparrow$$

Use of Nitrogen (II) Oxide

It is used as a catalyst in the industrial manufacture of sulphuric acid by the lead chamber process.

Nitrogen (IV) Oxide

Molecular Formula : NO_2 **Molecular Weight : 46**

In one molecule of this gas, there are two oxygen atoms and one nitrogen atom.

Preparation of Nitrogen (IV) Oxide

1. When nitrogen (II) oxide is mixed with oxygen, nitrogen (IV) oxide is formed.

$$2\,NO + O_2 \rightarrow 2\,NO_2 \uparrow$$

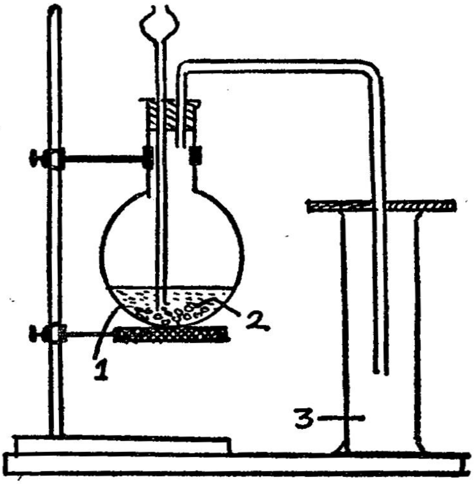
2. When nitrates of copper and lead are heated, they decompose to give nitrogen (IV) oxide and oxygen. The corresponding oxides of the metals are formed in the reaction.

$$2\,Cu\,(NO_3)_2 \rightarrow 2\,CuO + 4\,NO_2 \uparrow + O_2 \uparrow$$
$$2\,Pb\,(NO_3)_2 \rightarrow 2\,PbO + 4\,NO_2 \uparrow + O_2 \uparrow$$

Laboratory Method of Preparation of Nitrogen (IV) Oxide

Copper turnings are taken in a flat-bottomed flask fitted with a two-holed rubber stopper. Through one hole a thistle funnel is inserted. The tip of the funnel is kept touching the bottom of the flask. Through the other hole a delivery tube passes. The free end of the tube is kept inside a gas jar. Now strong nitric acid is poured into the flask through the thistle funnel. A vigorous reaction takes place between copper and the acid. Copper (II) nitrate and reddish brown nitrogen (IV) oxide are formed. The outcoming gas is collected in the gas jar

by the upward displacement of air because this gas is heavier than air.



Preparation of Nitrogen (IV) Oxide
1. Concentrated Nitric Acid 2. Copper Turnings 3. Nitrogen (IV) Oxide
Fig. 41

$$Cu + 4\,HNO_3 \rightarrow Cu\ (NO_3)_2 + 2\,H_2O + 2\,NO_2 \uparrow$$

Physical Properties

It is a reddish brown gas. It has a pungent smell. It is poisonous and heavier than air. At 20°C, it condenses into a yellow liquid. It is well soluble in water.

Chemical Properties

1. When a burning splinter is introduced into the jar, it continues to burn.

2. Burning magnesium and phosphorous continue to burn in this gas forming their respective oxides. Nitrogen is set free in this reaction. So this gas is an oxidising agent.

$$2\,NO_2 + 4\,Mg \rightarrow 4\,MgO + N_2 \uparrow$$

3. When nitrogen (IV) oxide is passed over heated copper, copper oxide and nitrogen are formed. This reaction shows that nitrogen (IV) oxide contains nitrogen and oxygen.

$$2\,NO_2 + 4\,Cu \rightarrow 4\,CuO + N_2 \uparrow$$

4. Nitrogen (IV) oxide liberates iodine from a solution of potassium iodide.

$$2\,KI + H_2O + NO_2 \rightarrow 2\,KOH + I_2 + NO$$

5. When this gas is passed through a solution of caustic alkalis, nitrates and nitrites are formed.

$$2\,KOH + 2\,NO_2 \rightarrow KNO_3 + KNO_2 + H_2O$$

6. This gas dissolves in cold water to give nitric acid and nitrous acid.

$$2\,NO_2 + H_2O \longrightarrow HNO_3 + HNO_2$$

When dissolved in warm water, it gives nitric acid and nitrogen (II) oxide.

$$3\,NO_2 + H_2O \rightarrow 2\,HNO_3 + NO \uparrow$$

7. (a) It decolourises acidified potassium permanganate solution.

(b) It turns acidified potassium dichromate solution green. These two reactions show that nitrogen (IV) oxide is a reducing agent.

Uses

1. It is used in the manufacture of nitric acid.
2. It is also used in the manufacture of sulphuric acid by the lead chamber process.

Questions

1. Mention some naturally occuring nitrogen compounds.
2. Describe the manufacture of nitrogen with a diagram.

3. How does magnesium react with nitrogen ?
4. Mention the physical properties of nitrogen.
5. State the uses of nitrogen.
6. State the names of the oxides of nitrogen.
7. What is laughing gas ?
8. Describe the preparation of nitrogen (I) oxide.
9. What happens when white phosphorus is introduced into a jar containing nitrogen (I) oxide ? Why ?
10. With examples show that nitrogen (I) oxide is a reducing agent.
11. Mention the uses of nitrogen (I) oxide.
12. Describe the preparation of nitrogen (II) oxide in the laboratary with a diagram. How is it identified?
13. How does nitrogen (II) oxide react with air?
14. What happens when burning magnesium is introduced into a jar containing nitrogen (II) oxide? What do you learn from this?
15. What happens when nitrogen (II) oxide is passed over heated copper turning?
16. State the uses of nitrogen (II) oxide.
17. Describe the prepration of nitrogen (IV) oxide with a diagram.
18. How will you prepare nitrogen from nitrogen (IV) oxide ?
19. Compare the properties of nitrogen (I) oxide, nitrogen (II) oxide and nitrogen (IV) oxide.

15. AMMONIA

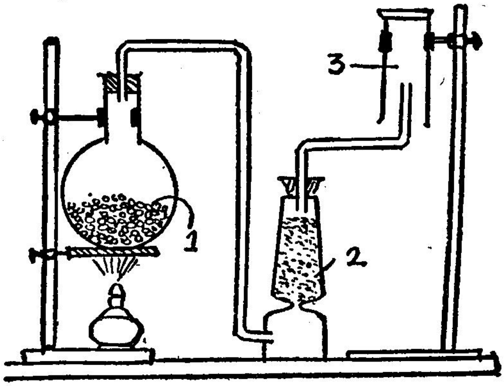
Molecular Formula : NH_3 **Molecular Weight : 17**

It was **Priestly** who discovered ammonia in 1774. He prepared the gas by heating a mixture of ammonium chloride and calcium hydroxide. He called the gas "Alkaline air". He found the same gas coming out when he heated strongly the horns and hooves of animals.

The gas is produced by the decay of organic matter. This is why, we get the smell of the gas in the stables and cattlesheds. The gas comes out when the urine of the animals decomposes giving out ammonia. This gas is a compound of nitrogen and hydrogen. In each molecule of the gas, there are one nitrogen atom and three hydrogen atoms. Hence the molecular formula of the gas is NH_3.

Preparation of Ammonia

Ammonium chloride and solid slaked lime (calcium hydroxide) are taken in the round bottomed flask. The mixture



Preparation of Ammonia
1. Ammonium Chloride+Slaked Lime 2. Quick Lime 3. Ammonia
Fig. 42

should be in solid state. The mouth of the flask is fitted tightly with a rubber stopper to which a delivery tube is attached. The other end of the delivery tube is attached to the bottom of the drying tower in which calcium oxide is kept.

Another delivery tube attached to the top of the drying tower ends in a gas jar placed in an inverted position as shown in the diagram. The mixture is heated. Ammonium chloride reacts with calcium hydroxide to give ammonia, calcium chloride and water. Calcium chloride remains in the flask. Ammonia gas with water particles passes through quick lime in

the drying tower. Water particles alone are absorbed by calcium oxide. The dry ammonia gas is collected by the downward displacement of air since it is lighter than air.

$$2\,NH_4Cl + Ca(OH)_2 \xrightarrow{\Delta} CaCl_2 + 2\,H_2O + 2\,NH_3 \uparrow$$

Manufacture of Ammonia on a large scale

Haber Process

Hydrogen and pure dry nitrogen are mixed in the ratio of 3:1 by volume and compressed to 200 atmospheric pressure. The compressed gas mixture is passed through steel tubes kept at a temperature of 500 °C having finely divided iron as a catalyst. A small amount of molybdenum is mixed with iron catalyst in order to accelerate the action of it. Molybdenum acts as a promoter. Nitrogen and hydrogen combine together in a the presence of the catalyst at 500 °C to form ammonia.

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3 \uparrow$$

This process was discovered by Haber, a German scientist and hence it is known as Haber process.

Physical Properties

It is a colourless gas with a characteristic pungent odour. It is lighter than air. When it is inhaled, it causes a copious flow of tears. One litre of water dissolves about 800 litres of ammonia gas. It is easily liquefied by compression and cooling. Liquid ammonia is volatile. The latent heat of vapourization of ammonia is 330 calories. Hence when ammonia evaporates, it causes much cooling in the surroundings. The gas is extremely soluble in water.

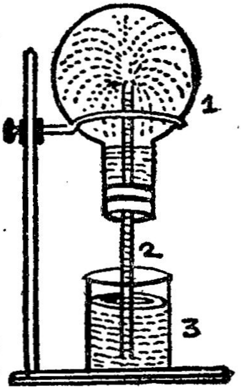
Fountain Experiment

The extreme solublity of ammonia in water can be demonstrated by the fountain experiment.

A round bottomed flask is taken and filled with ammonia gas. The flask is fitted with one holed rubber stopper through which a long glass tube passes. The inner end of the glass

tube inside the flask ends in a fine jet. The other end of tube is dipped into red litmus solution in a beaker. The apparatus is set up as shown in Fig. 42. a.

After some time the litmus solution rapidly rises into the flask through the tube. The solution dissolves much of the gas. Hence a partial vacuum is created inside the flask. So water rushes into the flask and flows out of the jet tube in the form of a fountain. The red litmus solution turns blue as it falls into the flask, showing that the gas is basic in nature.



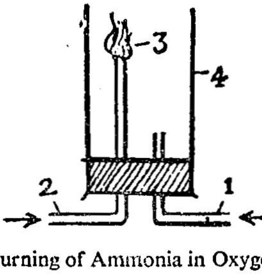
Fountain Experiment
1. Flask containing Ammonia gas
2. Jet Tube
3. Red Litmus Solution

Fig. 42. *a*.

Chemical Properties

(1) The gas is alkaline. When moist red litmus paper is put into the gas jar containing ammonia, it turns blue. When phenolphthalein solution is poured into the jar containing ammonia, it turns pink. Hence ammonia has the properties of bases. The gas dissolves in water to give an alkali namely ammonium hydroxide,

$$NH_3 + H_2O \rightarrow NH_4OH$$



Burning of Ammonia in Oxygen
1. Oxygen 2. Ammonia
3. Flame 4. Glass Cylinder
Fig. 43

(2) Introduce a burning candle in a jar of ammonia. It is put out. Ammonia is neither combustible nor a supporter of cumbustion. (3) Set up an apparatus as shown in Fig. 43. and burn ammonia gas. Ammonia in the presence of oxygen burns with a yellow flame forming nitrogen and water. This experiment shows that ammonia consists of nitrogen and hydrogen.

$$4\,NH_3 + 3\,O_2 \rightarrow 2\,N_2\uparrow + 6\,H_2O$$

(4) When a glass rod dipped in hydrochloric acid is brought near the jar of ammonia, dense white fumes of ammonium chloride are formed.

$$NH_3 + HCl \rightarrow NH_4Cl$$

(5) Ammonia reacts with sulphuric acid forming ammonium sulphate.

$$2\,NH_3 + H_2SO_4 \rightarrow (NH_4)_2\,SO_4$$

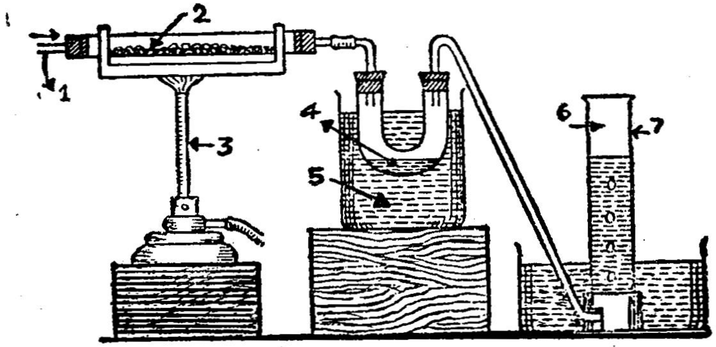
(6) Ammonia reacts with phosphorous (V) oxide forming ammonium phosphate. This is why phosphorous (V) oxide and concentrated sulphuric acid are not used as drying agents, to remove moisture from ammonia. Hence quick lime is used as a drying agent.

(7) Ammonia reacts with nitric acid giving ammonium nitrate.

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

(8) Ammonia as a Reducing Agent

Set up an arrangement as shown in Fig. 41. When ammonia gas is passed over heated copper (II) oxide, the



Ammonia as a Reducing Agent
1. Dry Ammonia 2. Copper Oxide 3. Burner 4. Water 5. Cold Water
6. Nitrogen 7. Gas Jar

Fig. 44

oxygen in the copper (II) oxide is removed. Copper (II) oxide is reduced to copper. In this reaction, nitrogen and water are formed. This experiment shows that NH_3 is a reducing agent.

$$3\,CuO + 2\,NH_3 \rightarrow N_2 \uparrow + 3\,H_2O + 3\,Cu$$

(9) When ammonia is passed over heated sodium and potassium, sodamide and potash amide are formed.

$$2\,NH_3 + 2\,Na \rightarrow 2\,NaNH_2 + H_2 \uparrow$$

Ammonia does not burn in air but when ammonia is passed rapidly over heated fine platinum-rhodium gauzes, the gas is oxidised to nitrogen (II) oxide.

$$4\,NH_3 + 5\,O_2 \rightarrow 4\,NO \uparrow + 6\,H_2O$$

Tests for Ammonia

(1) The gas is identified by its characteristic pungent odour.

(2) We can identify the gas from its reaction with hydrochloric acid when dense white fumes of ammonium chloride are formed.

(3) The gas gives a deep dark blue solution with copper sulphate solution.

Identification of the Elements in Ammonia

When ammonia reacts with oxygen, water and nitrogen are formed. The gas reacts with heated copper (II) oxide producing nitrogen and water. These two experiments show that nitrogen and hydrogen are present in ammonia.

Uses of Ammonia

(1) Liquid ammonia is widely employed as a refrigerant in the manufacture of ice.

(2) Ammonia is used in the manufacture of fertilizers like ammonium sulphate, ammonium nitrate and urea.

(3) Nitric acid is manufactured by oxidising ammonia.

(4) Ammonium chloride is used for tinning the cooking vessels and also as an exciter in the Leclanche cell.

(5) Ammonium carbonate is used as **smelling salt.**

(6) Liquid ammonia is used in dry washing.

(7) Urea fertilizer is manufactured using ammonia.

Questions

1. Describe the preparation of ammonia in the laboratory with a diagram.

2. Why should we not use concentrated sulphuric acid to dry ammonia ?

3. Describe an experiment to show that ammonia is highly soluble in water.

4. How are ammonium salts prepared from ammonia?

5. Mention a test to show that ammonia is a reducing agent.

6. Ammonia is a base. Give reasons.

7. What happens when ammonia is passed over heated copper (II) oxide?

8. State the uses of ammonia.

9. Mention a test for identifying ammonia.

Know Yourself

When iodine is added to a solution of ammonia in water a black precipitate is formed. This is known as nitrogen-tri-iodide (NI_3NH_3). It explodes itself when dry. If it is sprinkled on the ground, it will explode even due to friction.

For Thought

Generally concentrated sulphuric acid, phosphorous (V) oxide and anhydrous calcium chloride are used to dry gases. But to dry ammonia, they are not used.

16. NITRIC ACID AND NITRATES

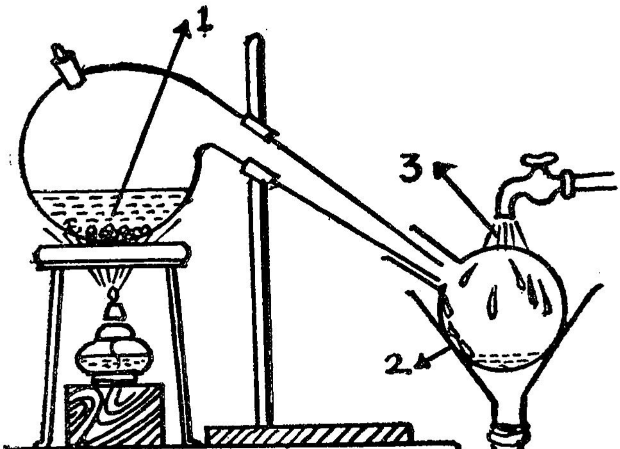
Molecular Formula : HNO_3 **Molecular Weight 63**

The chemical name for nitric acid is hydrogen nitrate. The Egyptians and the Indians have known this acid even from ancient times. **Glauber** was the first scientist to prepare it in 1650 by the action of concentrated sulphuric acid on nitre. The alchemists called this acid as "**Aqua Fortis**" (Strong Water). It was **Lavoisier** who discovered the presence of oxygen in the acid. This attacks almost all metals very vigorously.

Nitric acid is not found in nature. But nitrates like sodium nitrate (**Chile Salt Petre**) and potassium nitrate (**Bengal Salt Petre**) are found as natural deposits in some places.

Preparation of Nitric acid in Laboratory

It is prepared by the action of concentrated sulphuric acid on a nitrate. Either sodium nitrate or potassium nitrate is used.



Preparation of Nitric Acid

1. Potassium Nitrate + Con. Sulphuric Acid
2. Nitric Acid 3. Cold Water

Fig. 45

Take a glass retort fitted with a glass stopper as shown in the Fig. 45. A receiver is attached to the end of the retort. The retort is placed on a wire gauze kept on a tripod stand and clamped. **Potassium Nitrate** is taken in the retort. **Concentrated sulphuric acid** is added just to immerse the salt. On heating, potassium nitrate reacts with concentrated acid to give nitric acid vapours and potassium sulphate. Potassium sulphate remains in the retort. Nitric acid vapours get cooled and condense into liquid in the receiver cooled by water.

$$2\,KNO_3 + H_2SO_4 \xrightarrow{\Delta} K_2SO_4 + 2\,HNO_3$$

The acid thus got is yellow since nitric acid decomposes to give nitrogen (IV) oxide and gets dissolved in it. This can be got rid off by blowing air through the acid.

Sodium nitrate can also be used instead of potassium nitrate.

Caution

Since nitric acid corrodes things like cork or rubber, stoppers made of cork or rubber should not be used in the apparataus.

Manufacture of Nitric Acid on a large scale

Nitric acid is manufactured now by **Ostwald Process.** Large amounts of nitric acid can be obtained by this process at a low cost. Ammonia, manufactured by **Haber's Process** is mixed with ten times of its volume of air at $600°C$. Then the mixture is passed rapidly over heated platinum-rhodium gauzes which serve as catalysts. Ammonia is first oxidised by the oxygen in the air to nitrogen (II) oxide which combines with oxygen at a lower temperature forming nitrogen (IV) oxide. This nitrogen (IV) oxide dissolves in water to give nitric acid.

$$4\,NH_3 + 5\,O_2 \rightarrow 4\,NO \uparrow + 6\,H_2O$$
$$2\,NO + O_2 \rightarrow 2\,NO_2 \uparrow$$
$$3\,NO_2 + H_2O \rightarrow 2\,HNO_3 + NO \uparrow$$

Physical Properties

Pure nitric acid is a colourless liquid. Its relative density is 1·53. It boils and vapourises at 86°C. It fumes in air. It mixes with water in all proportions. It causes a yellow stain on the skin. When exposed to sunlight, it turns yellow or brown. It decomposes into nitrogen (IV) oxide, water and oxygen. This is why **the acid is kept in brown bottles.**

Chemical Properties.

The chemical properties of the acid can be classified under two heads : (a) **Acidic properties** (b) **Oxidising properties.**

(a) Acidic Properties

1. It turns blue litmus red.

2. This reacts with metallic carbonates with the evolution of carbon-di-oxide.

$$CaCO_3 + 2\,HNO_3 \rightarrow Ca\,(NO_3)_2 + H_2O + CO_2 \uparrow$$

3. It reacts with alkalis giving salt and water.

$$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$$

4. Magnesium displaces hydrogen from **cold and very dilute** nitric acid.

$$Mg + 2\,HNO_3 \rightarrow Mg\,(NO_3)_2 + H_2 \uparrow$$

Similarly manganese also reacts with cold dilute nitric acid.

$$Mn + 2\,HNO_3 \rightarrow Mn\,(NO_3)_2 + H_2 \uparrow$$

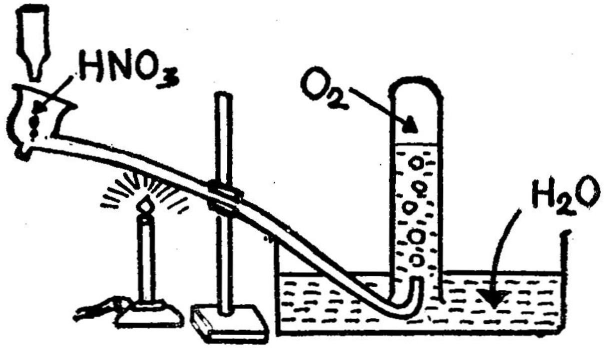
Other metals will not displace hydrogen from nitric acid.

Experiment

When the acid is heated, it decomposes into nitrogen (IV) oxide, water and oxygen.

$$4\,HNO_3 \rightarrow 4\,NO_2 + 2\,H_2O + O_2 \uparrow$$

From this we know that nitric acid is a powerful oxidising agent.



Nitric Acid as an Oxidising Agent

Fig. 46

(b) **Oxidising Properties**

(1) **Oxidation - Metals**

The reaction of nitric acid with metals depend on the concentration of acid, the nature of the metals and the temperature of the reaction.

Take, in different test tubes, metals like copper and lead. Add dilute nitric acid to the metals in each test tube. The following reactions take place :

$$3\,Cu + 8\,HNO_3 \rightarrow 3\,Cu(NO_3)_2 + 2\,NO\uparrow + 4\,H_2O$$

$$3\,Pb + 8\,HNO_3 \rightarrow 3\,Pb(NO_3)_2 + 2\,NO\uparrow + 4\,H_2O$$

Experiment

Take a small quantity of concentrated nitric acid in different test tubes. Add metals like copper, zinc, magnesium and lead. These metals react with the concentrated acid and nitrogen (IV) oxide is evolved. The respective metallic nitrates remain in the test tubes as solutions.

$$Cu + 4\,HNO_3 \rightarrow Cu\,(NO_3)_2 + 2\,NO_2 + 2\,H_2O$$
$$Zn + 4\,HNO_3 \rightarrow Zn\,(NO_3)_2 + 2\,NO_2 + 2\,H_2O$$
$$Pb + 4\,HNO_3 \rightarrow Pb\,(NO_3)_2 + 2\,NO_2 + 2\,H_2O$$
$$Mg + 4\,HNO_3 \rightarrow Mg\,(NO_3)_2 + 2\,NO_2 + 2\,H_2O$$

Aluminium, gold, platinum and iron do not react with concentrated nitric acid. But iron and aluminium react with dilute nitric acid.

(2) Oxidation of Non-metals

When sulphur is heated with strong nitric acid, it is oxidised to sulphuric acid. Nitrogen (IV) oxide is evolved in the reaction.

$$S + 6\,HNO_3 \rightarrow H_2SO_4 + 2\,H_2O + 6\,NO_2 \uparrow$$

Similarly when red phosphorous is heated with strong nitric acid, it is oxidised to orthophosphoric acid.

$$2\,P + 10\,HNO_3 \rightarrow 2\,H_3PO_4 + 10\,NO_2 \uparrow + 2\,H_2O$$

Carbon is oxidised to carbon-di-oxide when it is heated with concentrated nitric acid.

$$C + 4\,HNO_3 \rightarrow 4\,NO_2 \uparrow + 2\,H_2O + CO_2 \uparrow$$

Action with Compounds

When nitric acid is added to some heated saw-dust, the saw-dust catches fire taking oxygen from nitric acid.

Experiment

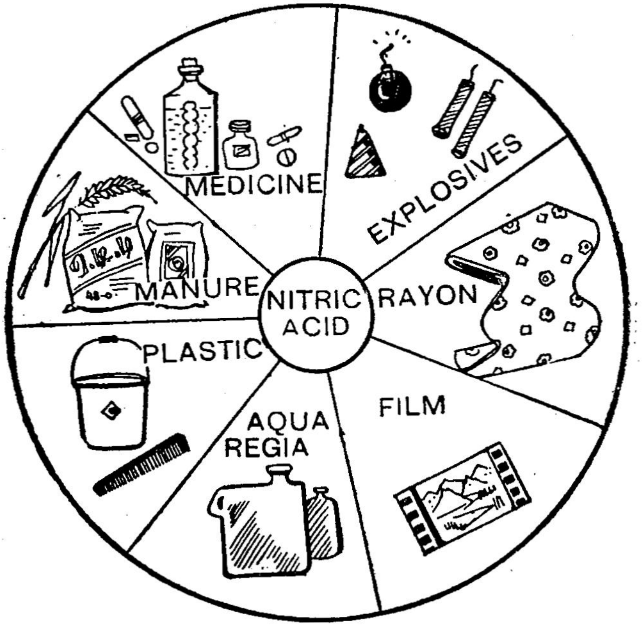
Add a few drops of turpentine to concentrated nitric acid taken in a porcelain dish. The turpentine burns with a large flame.

Test for Nitric Acid

Copper reacts with concentrated nitric acid to give reddish brown nitrogen (IV) oxide and green coloured solution of copper (II) nitrate. This is the test for the acid.

Uses of Nitric Acid

1. Nitric acid is used in the manufacture of explosives like, **nitroglycerine, gun cotton, and T.N.T.**



Uses of Nitric Acid
Fig. 47

2. Nitrates formed out of the acid are good fertilizers.

3. The acid is used to produce cinema films.

4. The acid is much used in the dye industry and in medicines.

5. It is used to prepare **Aqua regia** which dissolves gold and platinum.

6. The acid is used to engrave artistic designs on copper vessels.

7. The acid is used in bunsen and grove cells as depolariser.

8. It is used in the purification of gold.

Nitrates

Salts obtained from nitric acid are called nitrates. Nitrates are soluble in water. When nitric acid reacts with a metal or metallic hydroxide or a metallic carbonate, nitrates are formed. For example, nitric acid reacts with zinc oxide and forms zinc nitrate and water.

$$ZnO + 2\ HNO_3 \rightarrow Zn\ (NO_3)_2 + H_2O$$

Nitric acid reacts with magnesium hydroxide forming magnesium nitrate and water.

$$Mg\ (OH)_2 + 2\ HNO_3 \rightarrow Mg\ (NO_3)_2 + 2\ H_2O$$

It also reacts with carbonates to give nitrates. Carbon-di-oxide is evolved.

$$CaCO_3 + 2\ HNO_3 \rightarrow Ca\ (NO_3)_2 + H_2O + CO_2 \uparrow$$

Reactions with Nitrates

1. When sodium or potassium nitrate is heated, oxygen is evolved. In these reactions nitrates are reduced to nitrites.

$$2\ NaNO_3 \xrightarrow{\Delta} 2\ NaNO_2 + O_2 \uparrow$$
$$2\ KNO_3 \xrightarrow{\Delta} 2\ KNO_2 + O_2 \uparrow$$

2. Nitrates of heavy metals give nitrogen (IV) oxide and oxygen on heating.

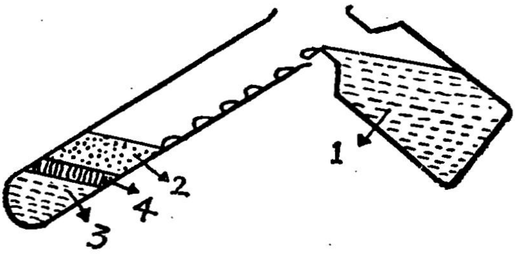
$$2\ Cu\ (NO_3)_2 \longrightarrow 2\ CuO + 4\ NO_2 \uparrow + O_2 \uparrow$$
$$2\ Pb\ (NO_3)_2 \longrightarrow 2\ PbO + 4\ NO_2 \uparrow + O_2 \uparrow$$

Test for Nitrates

(1) Take a nitrate salt in a test tube. Add some concentrated sulphuric acid. Add some copper turnings and heat. Reddish brown fumes of nitrogen (IV) oxide are evolved.

(2) Brown Ring Test

Take potassium or sodium nitrate solution in a test tube and freshly made iron (II) sulphate solution to it. Then holding



Brown Ring Test

1. Con. Sulphuric Acid · 2. Nitrate + Iron (II) Sulphate 3. Brown Ring
4. Conc. Sulphuric Acid

Fig. 48

the test tube slightly tilted, add concentrated sulphuric acid along the sides of the test tube slowly. The acid flows down and sinks to the bottom as it is heavy. The test tube gets heated. Cool it by keeping it in running water for some time, In the tets tube, at the junction of the acid and the solution. a brown ring is formed. This is the brown ring test. In this experiment a **brown compound** $FeSO_4NO$ is formed. This appears as **a brown ring.**

Uses of Nitrates

	Nitrates	Uses
1.	Calcium Nitrate and Ammonium Nitrate	Fertilizers.
2.	Silver Nitrate	In photography
3.	Lead Nitrate	In printing technology
4.	Barium Nitrate and Strontium Nitrate	In the preparation of fire works and sparklers

Questions

1. What is the chemical name of nitric acid? What are the elements present in it?
2. Describe the laboratory method of preparing nitric acid with a neat diagram.
3. Describe the preparation of nitric acid on a large scale.
4. What are the physical properties of nitric acid?
5. State the chemical properties and uses of nitric acid.
6. State examples to show that concentrated nitric acid is an oxidising agent.
7. State the reactions of concentrated nitric acid with metals.
8. Mention the metals that give hydrogen with nitric acid.
9. State the test to identify nitric acid.
10. What is the precaution to be taken in preparing nitric acid? Why?
11. Three bottles contain HCl, H_2SO_4 and HNO_3. How will you identify them?
12. How are nitrates prepared?
13. Illustrate with examples the action of heat on nitrates.
14. What are the uses of nitrates?
15. What is aqua regia?
16. Explain the brown ring test.

Know Yourself

1. **Nitroglycerine** is prepared by adding concentrated nitric acid and concentrated sulphuric acid to glycerine. It is used as an explosive. Its chemical name is **Glyceryl–tri–nitrate**.

2. T.N.T. is prepared by adding concentrated nitric acid and concentrated sulphuric acid to toluene. The chemical name of T.N.T. is **Tri Nitro Toluene.**

17. FIXATION OF NITROGEN

Fixation of Atmospheric Nitrogen

Nitrogen is very much essential for the growth of living things, plants as well as animals. Plants take nitrogen from the soil in the form of nitrates dissolved in water through their roots and prepare proteins. Men and animals cannot get their food if plants do not prepare proteins since they depend on plant kingdom for food. Explosives like T.N.T., dynamite, dyes and important nitrates are prepared from nitric acid which is a compound of nitrogen. Nitrogen compounds occurring in nature are not sufficient enough to the needs of the world. Atmosphere contains 78% of nitrogen in the free state. But plants utilize elementary nitrogen. Hence it is not of any use to them. Plants can take nitrogen only from nitrogen compounds soluble in water through their roots. They are incapable of assimilating free nitrogen.

The conversion of inactive free nitrogen, present in the atmosphere in large amounts into useful compounds of nitrogen, soluble in water so as to be easily absorbed by plants is known as fixation of atmospheric nitrogen.

In nature, nitrogen is fixed in the soil by two important ways.

1. Leguminous plants make use of nitrogen directly from the atmosphere. Millions of bacteria present in the root nodules of leguminous plants convert the atmospheric nitrogen into nitrogen compounds. Plants like pea, groundnut are examples of this type of plants.

2. During lightning and thunder, the atmospheric nitrogen and oxygen combine themselves to form nitrogen oxides. They dissolve in rain water to form nitric acid. On reaching the soil, the acid combines with the minerals of the soil to become nitrates.

$$N_2 + O_2 \rightarrow 2\,NO$$
$$2\,NO + O_2 \rightarrow 2\,NO_2$$
$$4\,NO_2 + O_2 + 2\,H_2O \rightarrow 4\,HNO_3$$
$$2\,HNO_3 + CaCO_3 \rightarrow Ca\,(NO_3)_2 + H_2O + CO_2 \uparrow$$

Fixation of Atmospheric Nitrogen by Synthetic Methods

Haber Process : This process is described in the lesson on Ammonia.

Birkeland-Eyde Process or Arc Process

When an electric arc is struck between the two electrodes, the temperature of the arc will be about 3000°*C*. When air is passed through the arc, the nitrogen and oxygen of the atmosphere combine to produce nitrogen (II) oxide.

$$N_2 + O_2 \xrightarrow{3000^\circ C} 2\,NO - 43200 \text{ cals}$$

The nitrogen (II) oxide is suddenly cooled to 1000°C. Otherwise it will decompose to give once again nitrogen and oxygen. Nitrogen (II) oxide is further cooled to a temperature of 150°C. and it is mixed with air. It combines with the oxygen of the air to give nitrogen (IV) oxide.

$$2\,NO + O_2 \rightarrow 2\,NO_2$$

Nitrogen (IV) oxide when mixed with water gives nitric acid.

$$4\,NO_2 + O_2 + 2\,H_2O \rightarrow 4\,HNO_3$$

Calcium carbonate is treated with this nitric acid, to get calcium nitrate, a good fertilizer.

$$CaCO_3 + 2\,HNO_3 \rightarrow Ca\,(NO_3)_2 + H_2O + CO_2 \uparrow$$

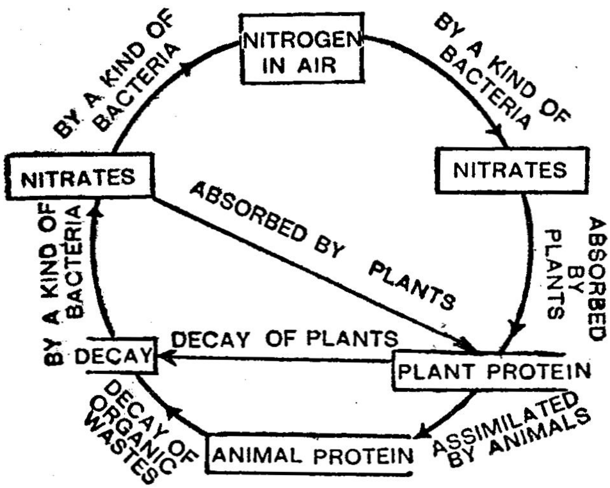
Calcium nitrate is known as **Norweigian Salt petre.**

Nitrogen Cycle

The nitrogen in the atmosphere is inert. Nitrogen is present to about 78% by volume in air. Man and plants cannot assimilate this nitrogen directly from air.

Nitrogen compounds are very much essential for living organisms. Nitrogen in air is made to combine with other elements to form nitrogen compounds by artificial and natural

means. These compounds reach the soil. Plants take these nitrogen compounds from the soil. They become food for the



Nitrogen Cycle
Fig. 49

animals. When living organisms die and decay, the nitrogen in them separates and once again reaches the atmosphere. This is known as nitrogen cycle.

Atmospheric Nitrogen reaching the Soil

During thunder and lightning, the nitrogen in the air combines with oxygen to give oxides of nitrogen. They dissolve in rain water to give nitric acid. When the acid reaches the soil, it is converted into nitrates in the soil.

The nitrifying bacteria living in the root nodules of leguminous plants like bean, pea, etc. take nitrogen from the air in the soil and convert them into compounds of nitrogen and store them in their roots.

Nitrogen compounds formed by the fixation of atmospheric nitrogen by artificial means, are added to the soil as fertilizers. By these three methods, nitrogen in the air reaches the soil in the form of nitrogen compounds.

Nitrogen in the Soil reaching Plants and Animals

Plants make use of nitrogen compounds in the soil and convert them into vegetable proteins. When men and animals consume the plants as their food, the vegetable proteins are converted into animal proteins. When plants, animals and organic waste decay in the soil, the nitrogen content in them is converted to ammonia by one kind of bacteria.

Another kind of bacteria converts this ammonia to nitrites The nitrites are transformed into nitrates by another kind of bacteria and these nitrates remain in the soil. Thus nitrogen in the soil made use of by plants and animals once again reaches the soil when they decay.

Nitrogen from the Soil getting back into the Atmosphere

Denitrifying bacteria present in the soil disintegrate the nitrogen compounds and set the nitrogen free. This nitrogen once again reaches the atmosphere,

Thus the atmospheric nitrogen reaching the soil from air and after travelling through plants and animal kingdom once again gets back into the atmosphere.

This process of fixation of atmospheric nitrogen from air to soil and utilisation of nitrogen by plants and animals, release of nitrogen back to the atmosphere is known as nitrogen cycle.

Only because of the nitrogen cycle the amount of nitrogen in the atmosphere remains more or less constant.

Questions

1. What is meant by fixation of atmospheric nitrogen?
2. Explain the methods of fixation of atmospheric nitrogen.
3. Describe nitrogen cycle with a diagram.
4. How do bacteria increase the fertility of the soil?

5. How do men get the required nitrogen from the atmosphere ?
6. How do lightning and thunder help the fixation of atmospheric nitrogen ?
7. How is atmospheric nitrogen converted into nitrates soluble in water?
8. Why does the amount of nitrogen in the atmosphere remain unchanged?

Know Yourself

1. The amount of nitric acid reaching the soil through the rain on account of lightning and thunder is estimated to be 2,50,000 metric tonnes per day.

2. Every year about 8 kilograms of nitrogen is reconverted into nitrogen compounds by bacteria in one hectare of land.

For Thought

If no drop fall from the cloud, not a green
blade of grass will be seen.

— Kural.

Part C - Biology

1. LEAVES

Leaves—the Food Factories of Plants

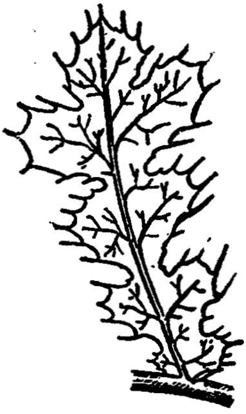
The leaves are regarded as lateral outgrowths of the stem. They are green, flat, expanded structures, borne on the stem at the nodes. They develop in an acropetal order on the stem. They are the most conspicuous organs of a plant.

Parts of a Leaf
1. Lamina 2. Petiole 3. Stipule
Fig. 1

They are considered to be the food factories of the plant. Hence they are the most important organs of the plant. Without green leaves no food materials can be produced; and without food, no plant or animal nor man can live. Hence the green leaves play a very vital role in the sustenance of life on earth.

Leaf - External Features

The leaf consists of the expanded part called the **'blade'** or **'lamina'**. The leaf base is the point of attachment of the leaf to the stem. The stalk of the leaf is known as **'petiole'**. It connects the lamina with the stem. Sometimes the leaf base bears a pair of lateral outgrowths. They are called **'stipules'**. Stipules are commonly found in dicotyledonous plants and are called **'stipulate'**. If there are no stipules as in *Ortabotrys*, it is called **'exstipulate'**. In *Hibiscus*, we can easily find the two free lateral stipules usually green in colour borne on the two sides of the leaf base. In **Rose**, two lateral stipules are adherent to the pedicel to a certain distance. Leaves without petioles as in *Calotropis* are described as **'Sessile'**. In sessile leaves, the lamina starts from the stem. The leaves which possess petiole are described as **'Petiolate'**. Eg : *Mango*, *Thespesia*. Normally the petiole is solid and cylindrical or slightly flattened on the upper side. But sometimes it is modified. In *Citrus*, it is flat and winged and in *Eichornia*, it is swollen and spongy, enclosing more air and helps the plant to float in water. In *Erythrina and Pongamia* the base of the petiole is swollen and flexible. This swollen base is known as **'Pulvinous'** and the leaves are said to be **'Pulvinate'**.



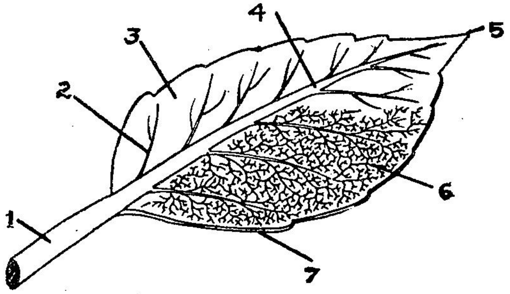
Sessile Leaf
Fig. 2

In Monocotyledonous plants, the leaf base becomes very prominent and winged. It is called **'sheathing leaf base'**. The petiole exposes the blade in the most favourable manner to light. It helps to lessen the effect of shock caused by rain and wind on the leaf blade. It conducts water and mineral substances from the stem to the lamina and carries the food prepared from the lamina to the stem.

The Lamina

It is the most important part of the leaf as it performs the most important physiological functions such as photosynthesis.

respiration and transpiration. It is normally a flat structure and can be differentiated into upper and lower surface. In many monocotyledons and some plants growing in shady situations, the leaf is placed in such an angle that both surfaces receive



Morphology of a Leaf

1. Petiole 2. Vein 3. Lamina 4. Midrib 5. Apex. 6. Small Veins 7. Margin

Fig. 3

equal light and hence there is no difference between the two surfaces. The lamina differs widely in different plants taking into consideration the different aspects such as shape, margin, apex, surface texture venation and simple and compound leaf.

Shape of the Lamina

The following terms are used to describe the various shapes of the lamina:

1. **Linear**: When the blade is long and narrow as in grass.

2. **Lanceolate**: When long and tapering at the ends like a lance, e.g. *Nerium, Polyalthia.*

3. **Oblanceolate**: This is similar to previous one with only a difference, the broadest part being near the stalk..

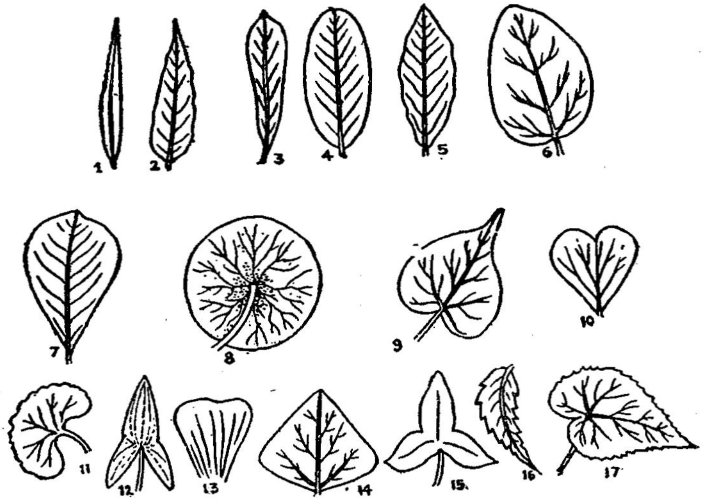
4. **Elliptic**: When the lamina is broadest at the middle with tapering ends and oval in shape as we see in *Jack* and *Vinca.*

5. **Oblong :** When the blade is two or three times long to its breadth with sides more or less parallel and ends rounded as in the **Plantain.**

6. **Ovate :** When egg shaped and slightly broader at the base than at the apex as in **Banyan.**

7. **Obovate :** When it is inversely egg shaped. e.g. *Terminalia catappa.*

8. **Orbicular :** When the blade is more or less circular as in **Lotus.**



Shapes of Leaves

1. Linear 2. Lanceolate 3. Oblanceolate 4. Elliptic 5. Oblong 6. Ovate 7. Obovate 8. Orbicular 9. Cordate 10. Obcordate 11. Reniform 12. Sagittate 13. Cuneate 14. Deltoid 15. Hastate 16. Falcate 17. Oblique,

Fig. 4

9. **Cordate :** When it is heart shaped as in *Thespesia populnea.*

10. **Obcordate :** When inversely heart shaped as in the leaflets of *Oxalis.*

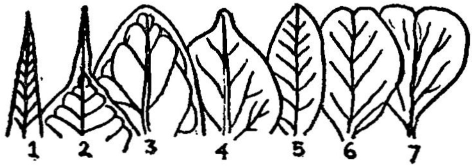
11. **Reniform :** When kidney shaped as in *Centella asiatica.*

12. **Sagittate:** When shaped like an arrow head, with two sharp straight lobes : eg. *Sagittarius.*
13. **Cuneate** or **Wedge shaped :** When the blade is broadest beyond the middle and tapers straight down.
14. **Deltoid :** When it is broadly wedge shaped and triangular as in leaflets of *Erythrina indica.*
15. **Hastate :** It is dart shaped, when the blade has two basal lobes which diverge sideways.
16. **Falcate** or **Sickle shaped :** When the blade is curved sideways as in *Melia.*
17. **Oblique :** When the right and left halves of the blade are not symmetrical.

Apex of the Leaves

The apex of the leaf or leaflet is described as

1. **Acute :** When the tip is sharp and pointed as in **Mango.**
2. **Acuminate :** When the tip is produced to a long fine point eg. *Ficus religiosa.*
3. **Obtuse :** When blunt as in **Banyan, Jack.**



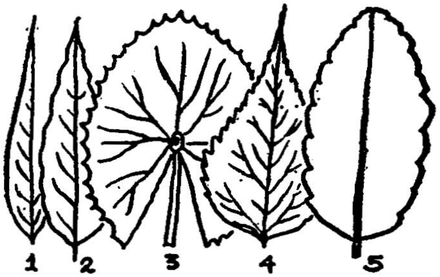
Apex of Leaves
1. Acute 2. Acuminate 3. Obtuse 4. Cuspidate 5. Mucronate 6. Retuse 7. Emarginate
Fig. 5

4. **Retuse :** When the depression is shallow and rounded as in *Calophylnm.*
5. **Mucronate :** When the midrib is prolonged beyond the lamina as in *Cassia auriculata.*
6. **Emarginate :** When the Apex has a shallow depression.
7. **Cuspidate :** When the leaf is broad and suddenly tapers at the apex.

Margin of the Leaf

The following descriptive terms are used for the edge or margin of the leaf base :

1. **Entire** : When quite even and smooth as in **Banyan.**
2. **Undulate** : When wavy as in *Polyalthia.*



Margin of the Leaves
1. Entire 2. Undulate 3. Dentate 4. Serrate 5. Crenate
Fig. 6

3. **Dentate**: When the triangular teeth are pointing outwards as in **Waterlily** and *Hibiscus.*
4. **Serrate** : When the sharp teeth are pointing towards apex as in *Acalypha.*
5. **Crenate** : When the teeth are all rounded as in *Bryophyllum.*

Surface of the Leaf

The surface of the leaves or leaflets may not be the same in all cases. Here we shall see a few types.

1. **Glabrous** : When quite smooth and shiny as in *Ficus religiosa* and *Vinca.*
2. **Pubescent** : When covered with soft, short hairs eg. *Hibiscus.*
3. **Glandular** : When there are sticky glandular hairs eg. *Jatropha glandilifera.*
4. **Gland-dotted** : When a number of spots are seen and each represents an oil gland.

Texture of the Leaf

With regard to thickness of the blade, a leaf is said to be :

1. **Fleshy or Succulent** : When thick and soft having plenty of water inside as in *Bryophyllum.*

2. **Coriaceous:** When not so thick, but tough and firm like leather eg. **Banyan, Jack.**

3. **Herbaceous:** When soft like a membrane as in *Balsam.*

Venation of the Leaf

The continuation of the pedicel into the blade is known as midrib. From this arises a number of branches called veins, or nerves. The way in which they are arranged in the blade is known as venation.

Functions of the Veins

1. Veins form the skeleton of the blade.
2. They expose the blade to sunlight.
3. They conduct water and minerals to all the parts of the leaf.
4. They conduct the food prepared inside the leaf to the stem.

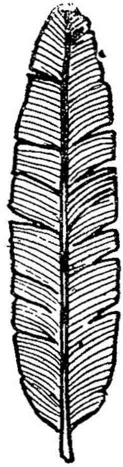
There are two types of venation, namely **Reticulate** and **Parallel.**

1. Reticulate

Numerous branches are given off from a very strong midrib on all directions and all the veins form a network covering the entire blade. This type is characteristic of dicotyledonous plants such as **Mango, Papaya.**

2. Parallel

In **Plantain leaf**, there are veins which run parallel to each other and they are more or less of the same size. This type is characteristic of all monocotyledonous plants.



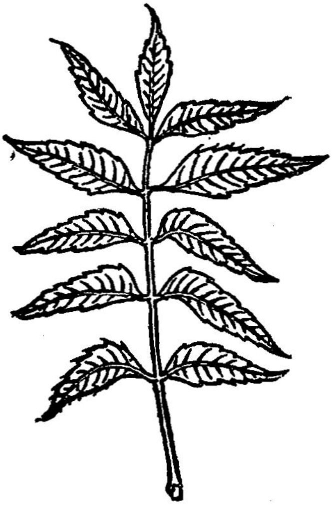
Parallel Venation Plantain Leaf
Fig. 7.

Simple Leaf and Compound Leaf

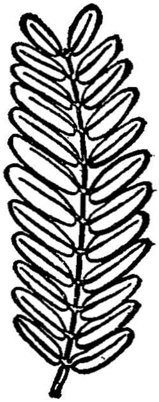
A leaf is said to be **simple** when only a single blade is attached to the patiole eg : **Mango.**

A leaf is said to be **compound** when there is a main petiole bearing a number of blades,each having a small stalk of its own. The main petiole is known as '**rachis**' and each blade is termed as a '**leaflet**'. eg: *Melia* and **Tamarind.** If the leaflets are

bigger, the compound leaf may look like a small branch. But it is not a branch and can be found out easily by noting the absence of terminal bud, nodes and internodes.



Imparipinnately Compound Leaf
Fig. 8



Paripinnately Compound Leaf
Fig. 9

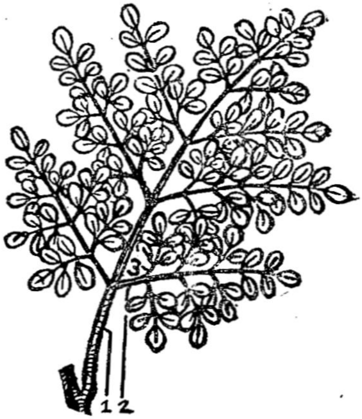
Compound leaves are broadly divided into '**pinnately compound**' and '**palmately compound.**'

In pinnately compound leaf, the leaflets are arranged laterally all along the length of the rachis and in opposite manner.

If the rachis ends in a pair of leaflets, the leaf is called '**paripinnately compound**' and if it ends in a single leaflet '**imparipinnately compound**'. Both of them are called **unipinnate**.

If the main rachis produces secondary rachis, on to which bear the leaflets, it is called '**bipinnately compound**' as in *Acacia arabica*. If the leaf is thrice pinnate (i.e) the primary gives rise to many secondary rachii which in turn give rise to tertiary rachii and bear leaflets, it is called of '**tripinnately compound**' as in *Moringa*. If the leaflets are found at the tips of the rachis radiating out like the fingers of the hand, it is said to be '**palmately compound.**'

Bipinnately Compound Leaf
Fig. 10



Tripinnately Compound Leaf (Moringa)
1. Primary Rachis 2. Secondary Rachis
3. Tertiary Rachis
Fig. 11

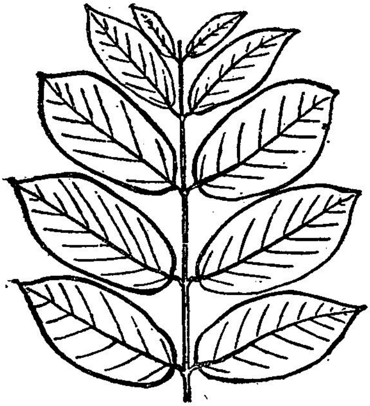
Arrangement of leaves (Phyllotaxy)

The mode of arrangement of the leaves on the stem is termed phyllotaxy. There are five types of such arrangements:

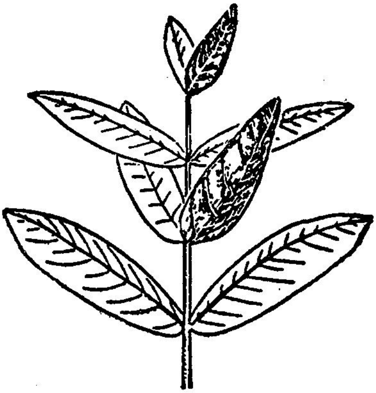
Alternate Arrangement
Fig. 12

1. **Alternate :** When there is only one leaf at each node eg. *Polyalthia.*

2. **Opposite** : When the leaves are arranged in pairs at each node eg. *Guava*. In *Calotropis*, the leaves are opposite and decussate.



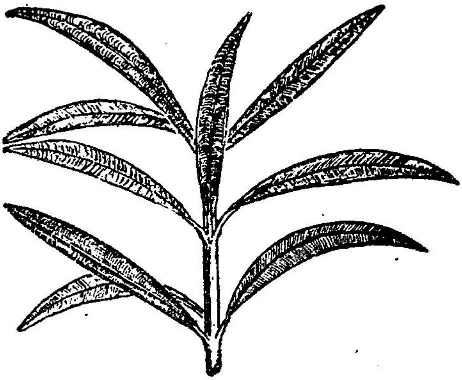
Opposite Arrangement
Fig. 13



Opposite and Decussate

Fig. 14

3. **Ternate** : When there are three leaves at each node. eg. *Nerium*

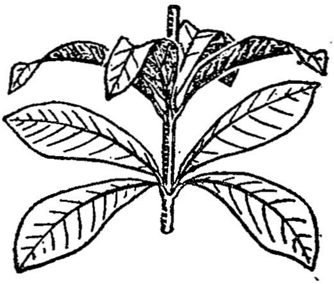


Ternate Arrangement

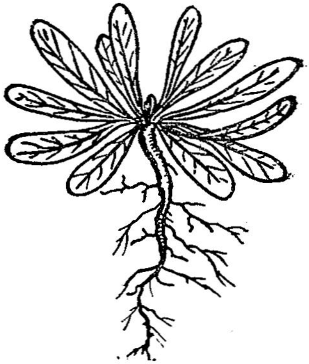
Fig. 15

4. **Whorled** : When there are more than three leaves at each node. eg. *Allamanda*

5. **Radical** : When the leaves arise in a cluster from **near** the ground level looking as though they start from the **root** directly. eg. *Mollugo.*



Whorled Arrangement
Fig. 16



Radical Arrangement
Fig. 17

Significance of Phyllotaxy

The various kinds of leaf arrangement help in exposing **all** the leaves to sunlight and air so that they may perform **their** functions efficiently.

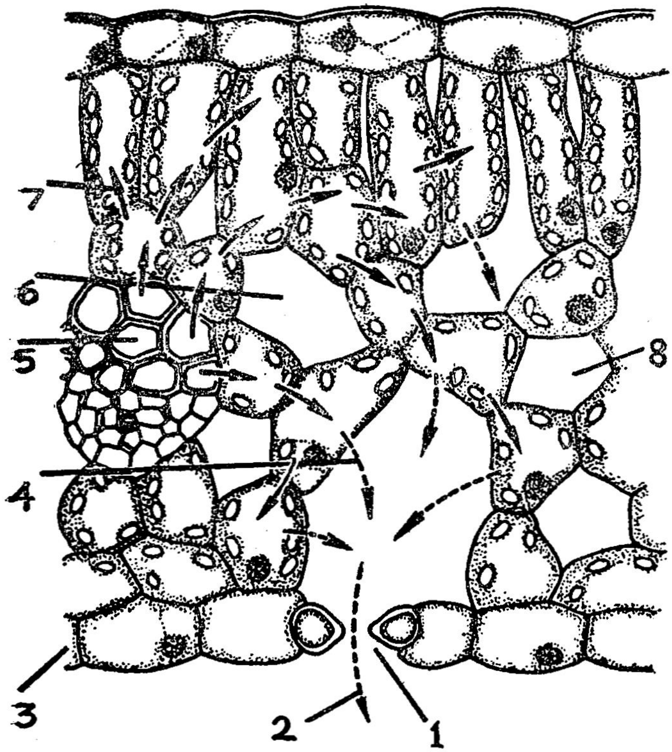
Internal Structure of a Leaf

Epidermis : A single layer of cells that is seen on **the** upper and lower surfaces is known as **'epidermis'**. The upper layer is called **'upper epidermis'** and the lower layer is called **'lower epidermis'**. The cells, are rectangular and closely packed with no air spaces between them. In the lower epidermis, there are minute openings called **stomata**. There is a thin continuous waxy layer on both the epidermial layers known as **cuticle.**

The epidermis protects the inner cells from bacteria, fungus and mechanical damage and reduces evaporation. It helps to maintain the shape of the leaf. The epidermal cells do not contain choloroplasts and are transparent. As a result of this, sunlight can pass through to the cells below which do contain chloroplasts.

Mesophyll : Between the two epidermal layers there are numerous parenchymatous cells. They constitute the **mesophyll**.

There are two layers of cells namely **palisade layer**, and **spongy layer.** In the palisade layer, cells are slightly elongated and arranged compactly, appearing cylindrical and possessing numerous chloroplasts, with narrow air spaces between them. Lying immediately below the epidermis, they receive and absorb most of the sunlight. The chloroplasts in palisade parenchyma are thus well suited to manufacture food materials. Chloroplasts are small often disc-like bodies made of protein. They contain **chlorophyll**, the green pigment which



Internal Structure of a Leaf
Movement of Water through a Leaf
1. Stoma 2. Exit of Water vapour 3. Epidermis (Lower)
4. Air space 5. Xylem 6. Intercellular Space
7. Palisade Parenchyma 8. Mesophyll
Fig. 18

gives green plants, their characteristic colour and which can absorb energy from sunlight and use it in the chemical build up of sugars and starch.

In the spongy layer, the cells do not fit closely together and hence large air spaces communicate with each other and with the atmosphere through the stomata thus allowing air to circulate in them and reach most of the internal cells of the leaf. The cells of this spongy layer contain fewer chloroplasts and receive less sunlight. Hence there is less photosynthesis.

Stomata : There are small openings in the epidermis and are more abundant on the lower side of the leaf. They are formed between two **guard cells,** which according to their internal pressure can increase or reduce the size of the stomata. The opening or closure of the stomata are connected principally with the intensity of light and in some cases with the loss of water.

Midrib and Vein : They support the leaf conducting water into it and food away from it. They contain vascular bundles surrounded by other fibrous and strengthening cells. Each cell of the leaf is not supplied with its own vein but the network of veins is very fine and water has to pass from a vein through only a few cells to reach the palisade cell.

Functions of the Leaf

(1) The most important function of the leaves is to make food in the form of carbohydrates by photosynthesis.

(2) Transpiration is another important function. Excess water in the plant body evaporates through the stomata in the leaf.

(3) Through the same minute openings, respiration takes place, oxygen of the atmosphere enters the blade and carbon-di-oxide goes out.

(4) Storage of water and food is done in some leaves.

(5) Scale leaves or bulbs also store food and water. Leaves of some plants like *Broyophyllum* and *Begonia* are capable of giving rise to new plants.

Modification of Leaves

Leaves are more susceptible to environmental influences than any other organ of the plant.

1. **Scale Leaves** : In Xerophytic plants, the leaves are so much reduced that they appear as scales which are thin, dry stalkless and brownish or colourless. In *Casurina* they are found in aerial shoots.

2. **Leaf Tendrils** : In plants which are weak stemmed, a part of the leaf or the entire leaf is transformed into tendrils which help them in climbing. The terminal leaflets of *Pea* plants are modified into tendrils. The petiole of *Clematis* helps the stem in holding to a support.

3. **Leaf Spines** : In *Opuntia*, the leaf buds in the axil are modified into a cluster of thorns and bristles which prevent the animals from eating the plant and thus protect it.

4. **Phyllode** : In plants like *Acacia melanoxeylon*, its petiole and in *Parkinsonia aculeta* its secondary rachii are flat and green and serve as photosynthetic organs as the leaf is suppressed to bring down transpiration. Such structures are called as phyllodes.

5. **Leaf Hooks** : In *Begnonia* species, the three terminal leaflets are modified into hooks which helps the plants to climb.

Photosynthesis

Photosynthesis is the most important activity of the leaf. It is the process by which plants with green leaves build up carbohydrates from carbon-di-oxide of the air and water that is absorbed by the roots and sent through the stem to the leaves. It is a chemical action of combination which takes place in the presence of chlorophyll which absorbs energy from sunlight. The byproduct of this chemical action is oxygen which escapes into the air. The process may be represented by the equation :

$$6\,CO_2 + 6\,H_2O \xrightarrow[\text{absorbed by chlorophyll}]{\text{energy from sunlight}} C_6H_{12}O_6 + 6\,O_2$$

It must be realised that this shows only the beginning and the end of a very complicated chain of chemical reactions involving many intermediate compounds and numerous enzymes which promote the different chemical changes.

Photosynthesis goes on mainly in the leaves though any green part of the plant can photosynthesise.

The leaves of most of the green plants are well adopted to the process of photosynthesis.

First of all, the broad flat shape offers a large surface for absorption of sunlight and carbon-di-oxide. Most leaves being thin, the distances across which carbon-di-oxide has to diffuse to reach the mesophyll cells from the stomata are very short. Numerous stomata on one or both surfaces allow the exchange of carbon-di-oxide and oxygen with the atmosphere.

The large intercellular spaces in the mesophyll provide an easy passage through which carbon-di-oxide can diffuse.

In the palisade cells, the chloroplasts are more numerous than in the spongy mesophyll cells. The palisade cells being on the upper surface will receive most sunlight and this will be available to the chloroplasts without being absorbed by too many intervening cell walls. The elongated shape of many palisade cells also is helpful.

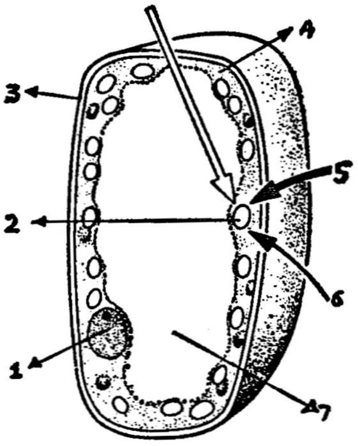
The branching network of veins ensures immediate water supply to the photosynthesizing cells.

Process of Photosynthesis in a Palisade Cell

Water passes into the cell by osmosis from the nearest vein. From the adjacent air spaces, carbon-di-oxide diffuses through the cellulose wall and into the cytoplasm. In the chloroplast which contains chlorophyll molecules of carbon-di-oxide and water are combined by a series of chemical changes. For some of these changes the energy is supplied to the chloroplast from sunlight absorbed by the chlorophyll. The product of photo-

synthesis is starch and during daylight, starch grains may be built up in the chloroplast.

Oxygen that is released during the process diffuses out of the cytoplasm through the cell wall into the air spaces and finally out of the stomata into the atmosphere.



Photosynthesis in a Palisade Cell

1. Nucleus
2. Chloroplast
3. Cell wall
4. Cytoplasm
5. Water
6. Carbon-di-oxide
7. Vacuole

Fig. 19

When photosynthesis takes place at a rapid rate, starch will get accumulated in the cell but enzymes are acting on the starch all the time turning it into soluble carbohydrates like sucrose which pass out of the cells and carried off in the sieve tubes of the phloem in the vascular bundle which is seen in the vein. The sucrose travels to the storage organs and is changed back into starch or passes to actively growing regions where it is oxidized during the process of respiration to provide energy for chemical reactions in the cell. It can also be concentrated in the cell sap lowering the osmotic potential of the vacuole which enables the cell to take in more water, increase its turgor and hence extend.

It can be converted into cellulose used to be built into new cell walls or to thicken existing ones. The sucrose also can be used as a basis for the synthesis of many other compounds such as proteins, fats, pigments etc.

All the starch in the leaf is converted back to sugar in darkness and removed.

Respiration goes on in the plant when the leaves are doing photosynthesis. During respiration, oxygen is used up, carbohydrates are broken down and water and carbon-di-oxide are given out.

During photosynthesis, carbon-di-oxide and water are taken in. Carbohydrates are built up and oxygen is excreted. In the green plants, as in all living organisations, respiration goes on all the time, but photosynthesis can take place only during day time when sunlight is available.

The rate of respiration may become equal to the rate of photosynthesis in the dim light of dawn and or dusk, so that all the carbon-di-oxide produced by respiration is used in photosynthesis and all the oxygen produced by photosynthesis is used up in respiration. The rate of carbohydrate breakdown in respiration is equalled by the rate of carbohydrate build up by photosynthesis and there is no net gaseous exchange with the atmosphere. The plant in this state is said to have reached its compensation point.

The case is different in bright light in which the rate of photosynthesis will be faster and in consequence, more oxygen will be produced than used up and more carbon-di-oxide used than produced by respiration.

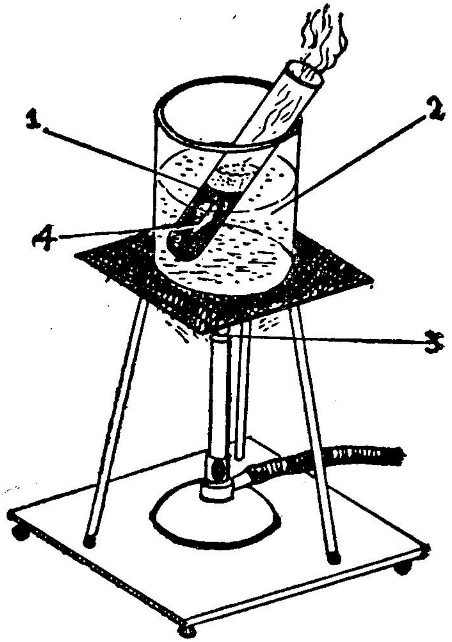
The net gaseous exchange with the atmosphere will thus be carbon–di–oxide taken in and oxygen given out.

In darkness no photosynthesis will take place and hence the plant will take in oxygen and give out carbon-di-oxide as a result of continuing respiration.

Testing a Leaf for Starch

The presence of starch is regarded as evidence of photosynthesis. Detach a leaf from a plant exposed to sunlight

for a few hours and dip it in boiling water for half a minute. This is done to kill the protoplasm by destroying the enzymes and to prevent any further chemical change. It also makes the



Removing Chlorophyll from a Leaf

1. Boiling Methylated Spirit 2. Boiling Water
3. Burner 4. Leaf

Fig. 20

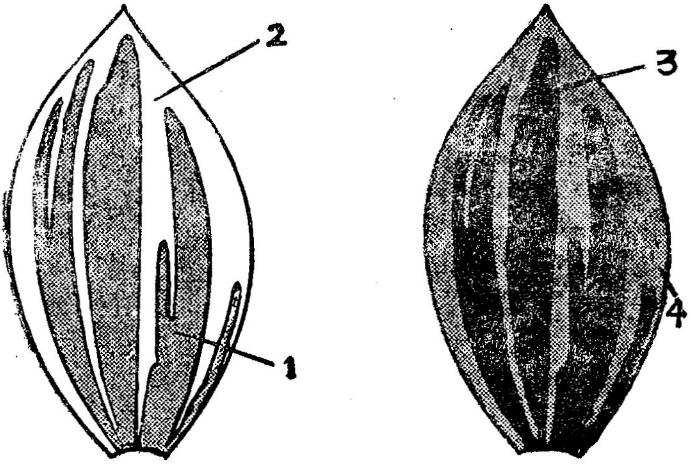
cell more permeable to iodine solution. The leaf is boiled in methylated spirit using a water bath until all the chlorophyll is dissolved out. Then the leaf which is white is taken out, washed in distilled water and then dipped in a solution of iodine in potassium iodide solution.

The white leaf turns blue at once showing the presence of starch.

Conditions Necessary for Photosynthesis

Chlorophyll is necessary for Photosynthesis

Use a varigated leaf of a crotons plant which has chlorophyll only in patches for this experiment. After a period of



To show that Chlorophyll is necessary
1. Green Parts with Chlorophyll 2. Parts without Chlorophyll
3. Blue 4. Brown
Fig. 21

destarching the leaf, the plant is exposed to daylight for a few hours and then detached. Make a sketch of the leaf carefully to show the green patches of the leaf and then it is tested for starch.

Only the parts that were previously green turn blue with iodine. So it can be inferred that photosynthesis has taken place only in those parts where chlorophyll is present.

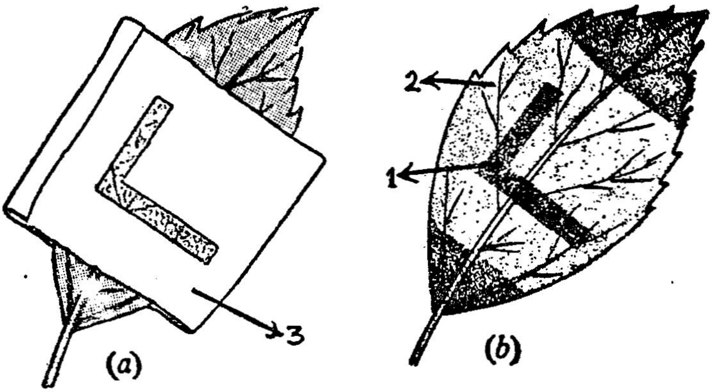
Destarching

Since the presence of starch is regarded as evidence of photosynthesis, the experimental plants must have no starch in their leaves. If they are potted plants, they are destarched by leaving them in a dark cupboard for two or three days. If the

plants are in the open place, experiments should be set up in the early morning before sunrise as almost all the starch will be removed from the leaves at night.

Sunlight Necessary for Photosynthesis

A simple shape 'L' is cut out from a piece of aluminium foil or thick black paper and is attached to a previously



Experiment to show that Sunlight is essential for Photosynthesis

1. Portion exposed to Sunlight 2. Portion not exposed to Sunlight
3. Aluminium Foil

Fig. 22

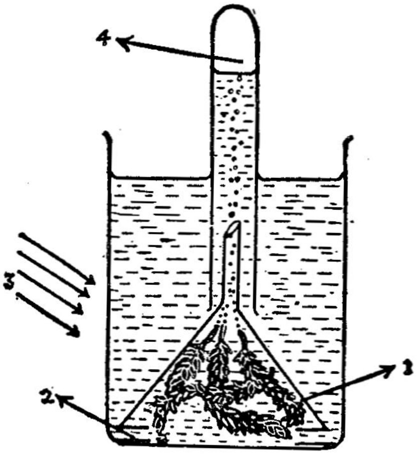
destarched leaf on both the surfaces as shown in Fig. 22. After keeping the leaf for 4 to 6 hours in daylight, the leaf is detached and tested for starch.

Only areas which had received sunlight turn blue with iodine. As starch has not accumulated in the areas not exposed to light, it is inferred that light plays an essential part in starch formation and hence in photosynthesis.

Oxygen is Produced During Photosynthesis

A short stemmed funnel is placed over some *Hydrilla* plant in a beaker of water preferably pond water. A test tube filled

with water is inverted over the stem of the funnel. The funnel is raised a bit above the bottom of the beaker to allow free circulation of water.



Liberation of Oxygen bubbles during Photosynthesis

1. Hydrilla Plant 2. Stand to support the Funnel 3. Sunlight
4. Oxygen.

Fig. 23

This apparatus is placed in sunlight for some time. Soon bubbles appear from the leaves of the hydrilla plant, rise and collect in the test tube. When sufficient gas is collected, the test tube is taken out and when a glowing splinter is inserted into it, at once it bursts into flames.

This shows that the gas collected in the test tube during photosynthesis is oxygen.

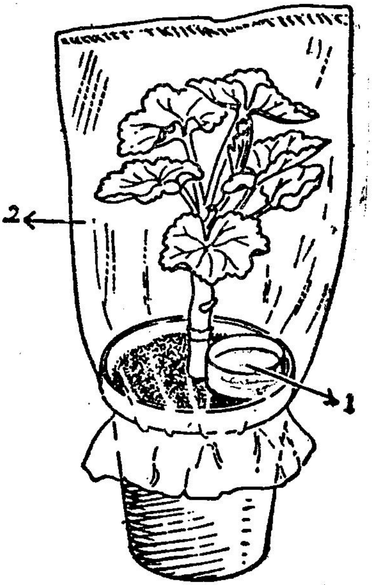
Carbon-di-oxide Necessary for Photosynthesis

Take two destarched, potted plants after watering and enclose the shoots in polythene bags as shown in Fig. 24. In one pot, keep sodalime in a dish. In another keep sodium hydrogen carbonate solution. Keep the plants in sunlight for several hours and detach a leaf from each plant and test them

for starch. In the pot where sodalime is kept, all the carbon-di-oxide within the polythene bag is absorbed by sodalime. So the leaves are deprived of carbon-di-oxide for photosynthesis. The leaf of the plant inside this bag when tested for starch does not turn blue.

Sodium hydrogen carbonate solution makes extra carbon-di-oxide available and the leaf which has taken carbon-di-oxide from atmosphere, enriched with it, turns blue with the iodine solution.

The fact that no starch is made in the leaf, deprived of carbon - di - oxide shows clearly that carbon-di-oxide is necessary for photosynthesis.



Carbon-di-oxide is necessary for Photosynthesis
1. Soda lime
2. Plastic Bag
Fig. 24

Transpiration

Transpiration is evaporation of water from the leaves and the subsequent movement of water through the xylem. It is a process which results in loss of water, most of which takes place through the leaves. The evaporation also occurs in stems and flowers.

Turgor pressure in the mesophyll cells forces water outwards through the cell walls. From the other surface of the cell walls, the water evaporates into the intercellular spaces.

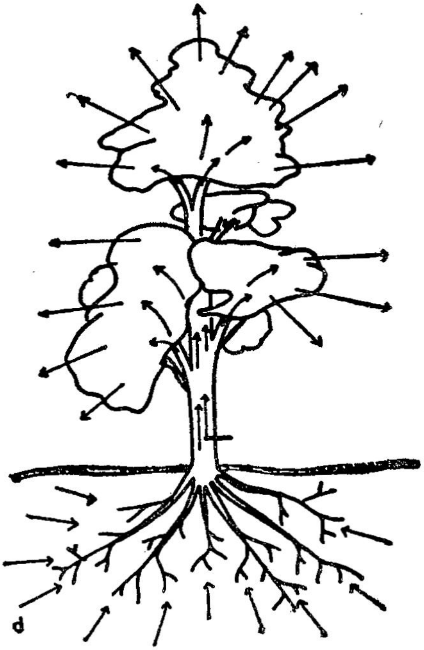
Significance of Transpiration

Transpiration is probably an inevitable consequence of photosynthesis. A large surface area is exposed to the atmosphere to absorb sunlight and carbon-di-oxide. A leaf

that is permeable to carbon-di-oxide must also be permeable to water vapour. Evaporation of water, therefore, must inevitably accompany photosynthesis. But transpiration produces beneficial effects to the plant.

When water evaporates from the leaf cells, it causes the turgor pressure to fall, which in turn makes the concentration of cell to rise and in consequence, a decrease in osmotic potential is produced.

Cells in this condition will absorb water from their neighbouring cells, and eventually from the xylem vessels in the leaf. This withdrawal of water by osmosis from the xylem vessels produces a tension, i. e. the water is subjected to pressures well below the atmospheric pressure. This tension draws water up



The Transpiration Stream
Fig. 25

to the vessels of the stems from the roots. This flow of water is called the **transpiration stream** and is dependent on the rate of evaporation from the leaves.

The transpiration is the cause for movement of water up the stems of plants including trees nearly to a height of 100 metres.

A tree on a hot day may evaporate hundreds of litres of water from its leaves. Of all the water that passes through the plant, only a tiny fraction is retained for photosynthesis and for maintaining the turgor pressure of the cells.

The transpiration stream carries mineral salts from the roots to the leaves but the rate of up take of salts from the soil is not directly dependent on the rate of transpiration.

Another beneficial effect of transpiration is that the temperature of the leaf is kept below harmful levels from the direct rays of the sun as there is absorption of the latent heat during rapid evaporation of water from the leaf surface.

Conditions that affect the Rate of Transpiration

Temperature : High temperature increases the capacity of the air for taking more water vapour and hence transpiration increases.

Humidity : When the atmosphere is saturated with water vapour, water can no more be absorbed from the plants and transpiration will be reduced. In a dry atmosphere transpiration will be rapid.

Air Movement : In still air the region around the leaf which transpires will become saturated with water vapour so that no more water can be absorbed from that leaf. Consequently transpiration is much reduced. But in moving air, the water vapour will be swept away from the leaf as fast as it diffuses out of the leaf. So transpiration proceeds rapidly.

Darkness : Less water vapour is lost during darkness when photosynthesis is impossible and carbon-di-oxide is not needed and the stomata are generally closed.

To control transpiration, trees in the tropics shed their leaves in the dry season.

Waxy cuticles and sunken stomata below the epidermis level in the leaves reduce transpiration.

If the size of the leaf is small, transpiration will be less rapid, depending on the surface area.

By producing spines or scales in the place of leaves and by producing latex, some plants protect themselves from excess transpiration.

To show that water vapour is given off during Transpiration

The shoot of a recently watered potted plant is completely enclosed in a transparent polythene bag which is tied round the base of the stem. Then the plant is allowed to remain for an hour or two in direct sunlight. The water vapour transpired by the plant will soon saturate the atmosphere inside the bag and drops of water will condense on the innerwalls of the bag. Then the bag is removed and all the condensed water is collected together and then tested with anhydrous copper sulphate which turning blue, proves that it is water.

Water is given off during transpiration

Fig. 26

Questions

1. "There can be no life on earth had there been no plants" — Explain.
2. Name any plant which has got stipules.
3. Mention plants having sessile leaves.
4. Mention the plants showing modification of the petiole.
5. What are the terms used to describe different varieties of lamina ?

6. What is the texture of the leaf in Bryophyllum?

7. What are the functions of the veins? Give examples for the two types of venation.

8. What are the differences between a simple leaf and a compound leaf?

9. What do you mean by phyllotaxy?

10. With a diagram show the internal structure of a leaf and explain the functions of the various parts.

11. What are the functions of the leaf?

12. Explain with examples the various modifications of leaf.

13. What is photosynthesis?

14. Explain the process of photosynthesis in a palisade cell.

15. How do you test for starch in a leaf?

16. 'No cholorophyll, no photosynthesis' Prove this with the help of an experiment.

17. What is destarching?

18. How can you prove that sunlight is necesssary for photosynthesis?

19. Is the presence of carbon-di-oxide a necessary condition for photosynthesis? Explain.

20. How will you demonstrate that oxygen is produced during photosynthesis?

21. Which part of the plant mainly conducts photosynthesis?

22. What are the differences between photosynthesis and respiration?

23. Draw diagrams to show chlorophyll and sunlight are necessary for photosynthesis.

24. What are the requirements for photosynthesis and how are they met in a terrestrial plant as well as an aquatic plant?

25. Why shoots deprived of light grow very tall and shoots illuminated from one side grow towards the light source?

26. What do you mean by transpiration?

27. How does transpiration take place in the leaves?

28. What are the effects of transpiration?

29. What are the conditions that affect the rate of transpiration?

30. How do plants adapt themselves to reduce transpiration?

31. How will you prove that water is given off during transpiration?

32. Describe an experiment to prove that water vapour is given off during transpiration?

33. Why should cutting a deep ring of bark from a tree cause its death?

34. Outline the path taken by water from the soil through the roots, stem and the leaves of a plant and into the atmosphere as vapour. Explain briefly the forces causing its movement at each stage.

Do It Yourself

(1) Collect different kinds of leaves. Place them in between blotting papers and keep them under three or four heavy books for a week or two.

Now remove the leaves carefully and paste them on a paper and write the name of the leaf and its kind underneath. Preserve it carefully.

(2) Take a small leaf or a piece of a large leaf and hold it in forceps and plunge it into a beaker of hot water (about 80°*C*). Bubbles appear. Observe whether

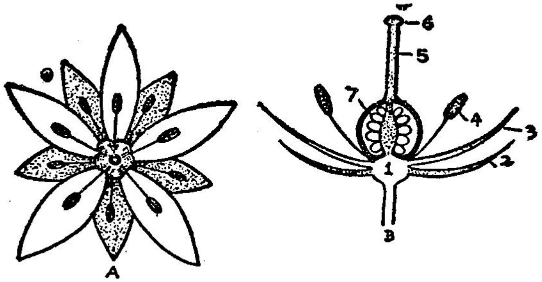
they are seen on both the sides of the leaves. If so, count the number of bubbles in each of them. Find out the reason for the appearance of bubbles, and difference in their numbers.

2. FLOWERS

Flowers are the reproductive organs of higher plants. They produce seeds. Most flowers have both male and female reproductive organs.

A flower is homologous with the vegetative shoot. It is composed of a very short axis on which a few whorls of leaves are arranged. Usually there are four whorls of floral leaves arranged one within the other.

The outermost whorl of floral leaves is collectively known as the **calyx**. The floral leaves that constitute the calyx are called **sepals**. They are normally green in colour, small and triangular in size. They may be either united or free. If united to form a cuplike structure, the calyx is called **gamosepalous**. If free, the calyx is called **polysepalous**. The sepals enclose and protect the rest of the flower while it is in the bud.



(A) Floral Arrangement (B) L. S. of a Flower

1. Thalamus 2. Calyx 3. Corolla 4. Stamen 5. Style
6. Stigma 7. Ovary

Fig. 27

The next inner whorl or floral leaves is collectively called **corolla.** It consists of petals which are often coloured and scented. They attract insects, bees and butterflies which visit

the flowers and collect the nectar and pollen, pollinating the flowers as they do so. Small grooves or darker lines in the petals called **honey guides** are there to direct the insect to the nectaries within the flower. The calyx and the corolla are collectively known as the **perianth.** The distinction between calyx and corolla is not seen in monocotyledonous plants.

Corollas are of four kinds viz. (1) Polypetalous regular corolla (2) Polypetalous irregular corolla (3) Gamopetalous regular corolla and (4) Gamopetalous irregular corolla.

The **androecium** is the male part of the flower. It contains the stamens. The **stamen** consists of the stalk named **filament** at the end of which is a two lobed **anther** which contains pollen grains in four pollen sacs. The pollen grains contain the **gametes,** the male reproductive cells. The stamens may be all free or united in various ways.

The female part of the flower is the **gynoecium.** It contains **carpels** which may be either single and solitary, many and separate from each other, or few and joined together. Inside the carpels, we find the female gametes called the **ovules** enclosed in a case called **ovary** from which extends the **style,** expanded or divided at one end into a **stigma** which receives pollen. As a result of pollination, fertilisation of ovules takes place and they become seeds. The ovary will become the fruit. The wall of the ovary develops into the pericarp of the fruit.

Nectaries

These are glandular swellings often found at the base of the ovary or on the receptacle which produce a sugary solution called nectar. Insects visit the flower to drink or to collect the nectar.

The Style

The style is an elongated tubular structure, generally tapering from below upwards. Usually, it is found right on the summit of the ovary. The tip of the style is called **stigma.** It may be either simple or branched, The stigma is slightly sticky to touch.

Ovule

Ovules are small oval structures found inside the ovary. Each ovule is an immature seed. It has two coats, an outer and an inner coat known as the **integuments.** Within these integuments, there is a special kind of tissue called the nucellus. The most important part of the ovule is called the embryo sac. It is lying embedded in the nucellus. There is a minute opening at the top of the integuments called **micropyle.**

The Inflorescence

Flowers, when occur in clusters, are generally arranged on branches which are quite distinct from the vegetative branches. This floral branch is called inflorescence. The main axis on which the flowers are arranged is called the **peduncle.** The stalk with which each flower is attached to the peduncle is called the **pedicel.** Some flowers are without stalks and are said to be **sessile.**

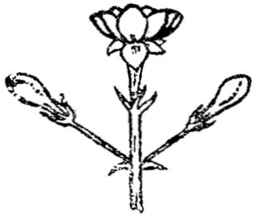
If the main axis does not end in a flower and grows continuously, that type is **racemose inflorescence.** In this type,

Raceme Inflorescence
Fig. 28

the flowers are arranged directly in acropetal succession. eg. *Crotalaria.* The main axis may give rise to a number of branches in acropetal succession and the flowers are arranged in a similar manner eg. *Caesalpinia.*

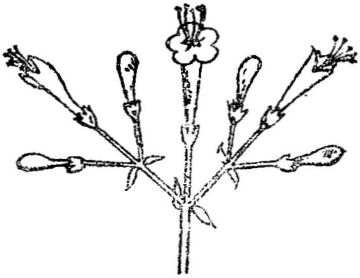
If the main axis ends in a flower, that type is called **cymose inflorescence.** The single flower may be terminal

eg. *Poppy* or axillary eg. *Thespesia.* At times a cluster of flowers is seen. There it can be found that the middle flower



Simple cyme

Fig. 29



Dichasial cyme

Fig. 30

is the oldest while the side ones are younger. The development of the flowers is **centrifugal** from the centre onwards.

There are some other special types of inflorescence namely **Hypanthodium** as in *Fig* and **Verticillaster** as in *Leucas.*

Pollination

The deposition of the pollen on the stigma of flower is known as pollination. It is of two kinds namely self pollination and cross pollination. If the pollen gets deposited on the stigma of the same flower, the process is called **self pollination.** If the pollen of one flower is deposited on the stigma of another flower either on the same plant or on a different flower of the same kind that process is called **cross pollination.** In nature, cross is more prevalent than self pollination. Nature abhors self pollination and favours only cross pollination. When cross pollination takes place, the characters of both the plants are continued and this leads to the production of new varieties of plants. The seeds produced as a result of cross pollination are bigger, more numerous and germinate into better plants than those produced by self pollination. Frequent self pollination results in the gradual deterioration of the plants. When all chances of cross pollination have failed, then self pollination takes place.

The transference of pollen is effected through the agencies of animals, wind and water.

Pollination by Animals

Birds, squirrels, insects, bees, moths, butterflies and flies are well adapted to bring about cross pollination. Flowers offer various kinds of attraction so that the different kinds of insect visit the flowers with great eagerness. Often some flowers offer pollen as food to insects. Some offer honey, which is secreted by special glands called nectaries. The various colours of the flowers are another attraction. Butterflies, bees and moths are attracted by colour. Another very important attraction is the smell of the flowers, which attracts insects from long distances particularly at night. The moth flowers open during night time, eg. *jasmine*. The butterfly flowers open during day time. When the insect visits a flower and leaves it after sucking the honey, the pollen is carried by some parts of the body and during its visit to another flower, the pollen is deposited on the stigma of the flower.

Birds like crows and mynahs help cross pollination. Bird pollinated flowers are usually big in size and brightly coloured, the common colour being scarlet. These flowers secrete plenty of honey eg. *Bombosa*.

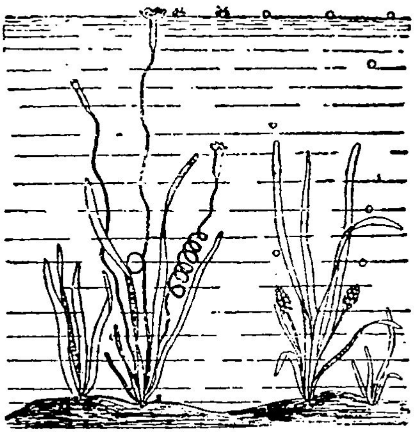
Pollination by Wind

Wind pollinated flowers are generally small in size and are devoid of attractive colours, honey and smell. But the quantity of pollen produced by them is very great allowing wastage. The pollen is dry, loose and powdery, that it is easily carried by the wind. The filaments of stamens are long and extended and the anthers are versatile, so that they swing freely on the filament and move with every breath of wind. The stigmas being long and feathery, are specially adapted to catch the pollen.

Pollination by Water

In entirely submerged plants like, *Elodea*, *Vallisneria* and *Hydrilla* pollination takes place with the help of water. In

Vallisneria, the male flowers are produced in clusters and when mature, break off and come to the surface of water. Each flower has three perianth parts and two stamens.



Pollination by Water-Vallisneria

Fig. 30 (a)

The female flowers are solitary and are provided with long stalks which bring them to the surface of the water. Surrounding each female flower, there is a depression on the surface of the water and when the male flowers come to this, they shoot towards the female flower. The anthers burst at that time and the pollen grains stick to the stigma. After pollination the stalk of the female flower coils spirally and draws it under water and the fruit develops under water.

Contrivances that ensure Cross Pollination

1. Production of unisexual flowers. eg. *Pappaya*, *Pumpkin*

2. In unisexual flowers, anthers and the stigma mature at different times. In *Helianthus*, the anthers ripen before the stigma. In plants like **paddy, wheat, maize**, the stigma ripens before the anthers.

3. In **leguminous plants**, the. pollen from other flowers is more effective than the pollen from the same flowers.

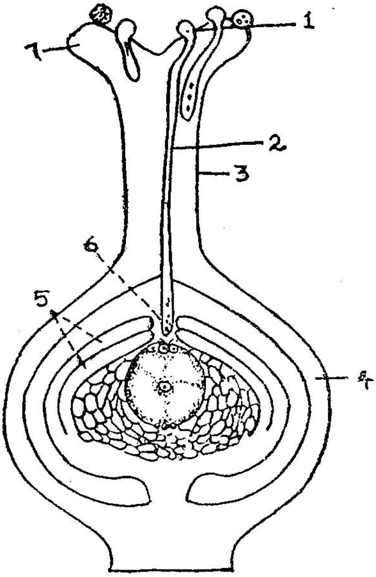
4. In some plants like *Abutilon,* the pollen of the same flower has no effect on the stigma.

5. In many bisexual flowers, self pollination is not possible because of the positions of the anthers and the stigma. The anthers may be placed above the stigma whose surface alone is receptive and the stigma may project beyond the anthers. eg. *Portia*

6. Some flowers have short styles and long stamens; some others have long styles and short stamens.

Fertilisation

The pollen grains carried by the different agencies to the stigma get attached to it as it is sticky. Then they start



Fertilisation

1. Pollen Grain 2. Pollen Tube 3. Style 4. Ovary 5. Ovule-outer inner integuments 6. Sperm 7. Stigma

Fig. 31

growing. Each pollen grain has got two coats, the outer and the inner. The outer is thick and the inner is thin and

delicate. When it starts growing or germinates, the inner one grows into a long tubular structure called the pollen tube. This penetrates the stigma and grows through it and the style. It reaches the ovary finally and enters the ovule through the micropyle. It grows further and reaches the embryo sac. At this time, the tip of the pollen tube now breaks open and the contents flow through the tube into the embryo sac. One male gamete of the nucleus fuses with the female gamete, the egg and the second male gamete or nucleus fuses with the large nucleus situated in the centre of the embryo sac. Now the ovule and the egg is said to be fertilised. The fertilised ovule is now known as the seed.

As soon as fertilisation takes place, the stamens and the petals of the flower drop off. The style too drops off in most of the cases and the ovary develops into the fruit.

Questions

1. Draw a diagram of a flower and label its parts.
2. What are the functions of the corolla and the calyx ?
3. Name the different kinds of corolla.
4. Describe the male part of a flower.
5. What does the female part of a flower consist of ?
6. What is the purpose served by nectaries ?
7. What are unisexual and bisexual flowers ?
8. What are the two kinds of infloresence ?
9. What are cross pollination and self pollination ?
10. How do animals, wind and water help in cross pollination ?
11. What are the contrivances that prevent self pollination?

12. How does fertilisation take place in a flowering plant ?

13. Pollination may occur without fertilisation taking place but fertilization will not occur without pollination. Explain why this is so.

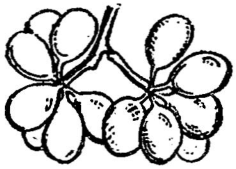
Do It Yourself

Grow different kinds of roses, sunflower plants and bougainvillea in the school garden. Keep one or two common plants also. This would add to the beauty of your school.

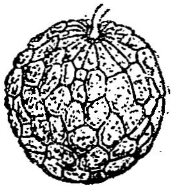
3. FRUITS AND SEEDS

Fruits

The fruit is the fertilised and ripened ovary. If it is developed from a single pistil, it is said to be a simple fruit and if from an apocarpous pistil, it is said to be an aggregate fruit.



Aggregate Fruit
Polyalthia
Fig. 32



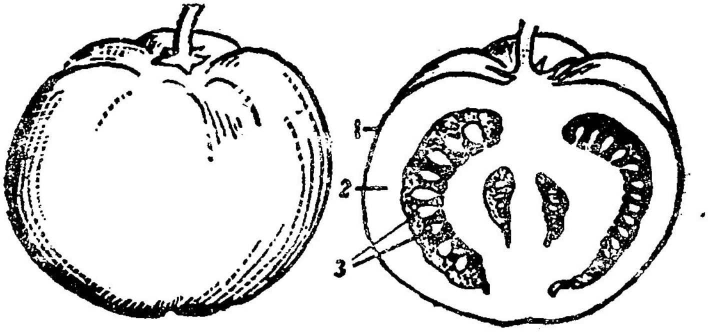
Aggregate Fruit
Anona
Fig. 33

In *Polyalthia*, the fruits that are formed are free from one another so as to form a cluster of fruits. In *Anona*, all the small fruits fuse together to give rise to single fruit. The aggregate fruit may either be dehiscent or indehiscent and when indehiscent, either dry or fleshy. In jack tree the entire inflorescence gives rise to a fruit. The ovary of each flower develops into a fruit and the fruits of all the flowers of the inflorescence fuse together so as to form a compound fruit known as collective or multiple fruit. The wild apple and the fig are examples of multiple fruit.

Simple Fruits

There are two kinds of **simple** fruits. **Fleshy fruits and Dry** fruits.

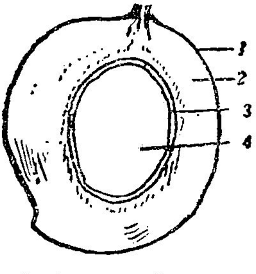
Fleshy Fruits : *Tomato, brinjal, grape, plantain* and *date palm* are examples of fleshy fruits. They are called **Berries.**

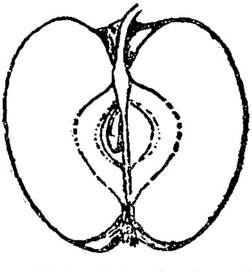


Simple Fruit—Fleshy Fruit
Cross Section of Tomato
1. Epicarp 2. Mesocarp 3. Seeds
Fig. 34

In this type, the pericarp is succulent and is **differentiated** into two portions, outer and inner. **The outer portion** forms the skin of the fruit and is called **epicarp the inner part** which is juicy has the seeds embedded in it, **It is called the mesocarp.**

Mango is different from berry, because its **pericarp is** differentiated into three portions—outer pericarp, fleshy





L.S of Mango (Drupe)
1. Epicarp 2. Mesocarp
3. Endocarp 4. Seeds

L.S of Apple (Pome)

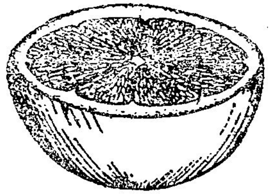
Fig. 35

mesocarp and hard endocarp. Inside the endocarp lies the seed. This type of fruit is known as **Drupe.** *Coconut* belongs to this group.

Apple comes under a different group called **Pome.** The fleshy part is the torus or thalamus which forms the major portion of the fruit.

Melon and *Cucumber* belong to the Pepo group. The edible portion in them consists of the placentas and the inner portion of the pericarp which becomes swollen and juicy. The outer portion of the pericarp forms a thick leathery covering.

Lemon and *oranges* belong to the **Hesperdium** group. The pericarp in them is differentiated into three regions. The outer thick-leathery skin with oil glands is the epicarp, to the innerside of which is closely attached the white spongy underskin called the mesocarp. Inside the mesocarp there are a number of membranous partitions which divide the inner part of the fruit, into a number of cells. These partitions form the endocarp from whose walls numerous thin swollen hairs, containing a syrupy juice, grow out.



T. S. of Hesperidium (Orange)
Fig. 36

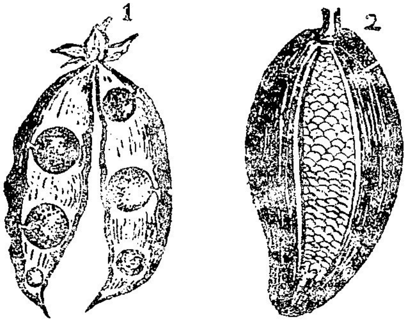
Dry Fruits

There are two kinds of dry fruits-**dehiscent** and **indehiscent.** If the dry pericarp of the fruit splits or breaks open so as to liberate the seeds, that fruit is called a dehiscent fruit. If a dry fruit does not exhibit such dehiscence, it is called **indehiscent fruit.**

Dry Dehiscent Fruits

In common bean, the pericarp splits open along the two margins into two halves. Such fruit is said to be a **legume** or **pod.** After dehiscence, the two halves of fruit get twisted to scatter the seeds.

In *Calotropis*, the pericarp opens only along one of the margins and that too generally along the ventral suture i.e



1. Legume 2. Follicle

Fig. 37

the margin along which the seeds are attached. That type of fruit is called a **follicle.**

In the fruit of *Acacia*, a number of transverse constrictions are found between the seeds. As a result, the fruit breaks out transversely into one seeded parts. Such a fruit is called **lomentum.**

Legume, follicle and lomentum develop from monocarpellary pistil.

Capsules are fruits developed from a syncarpous pistil. These capsules dehisces in different ways. They are named accordingly.

When the pericarp splits longitudinally along the middle of each cell or loculus into as many halves as there are carpels so as to expose the interior of each cell, the capsule is said to be **loculicidal capsule**, eg. **Hibiscus** (lady finger).

When the pericarps split longitudinally along the partitions of septa so that each septum splits up into two halves and the seeds are not exposed, such a capsule is called **septicidal capsule.**

In **septifragal capsule**, the pericarp will break away after the dehiscence, unlike in loculicidal and septicidal capsules, the pericarp is still attached to the septa eg. *Datura.*

In *poppy*, when the fruits are ripe, a number of small holes are developed on the top of the fruit and the seeds escape through the holes. This is an example for **Porous capsule.**

It *mustard* fruit, the pericarp splits into two halves from below upwards leaving the septum in the middle like a frame work with the ovules attached to either margin. This type is known as **Siliqua.**

In a **Schizocarp,** dehiscence takes place septicidally into as many parts as the number of capsules and each part is liberated and they do not dehisce further eg, *Abutilon* and *Coriander.* But in *Castor*, further dehiscence takes place loculicidally to liberate the seed.

Dry Indehiscent Fruits

This type of fruits have no splitting of the pericarp to liberate the seed but the pericarp ruptures only when the seed germinates.

In *Helianthus* the fruit is one seeded and one celled and is very small. The pericarp is dry membranous and free from the seed coat. This type is known as **Achene.**

In *Amarantus*, the seed in the fruit is small and occupies only a portion of the fruit unlike the achene in which the seed is found filling the entire interior portion of the fruit. This type is called **Utricle.**

In *Wheat* and *Maize*, though the fruit looks like an achene, there is some difference (i.e.) the seed coat is fused with the pericarp and that the grain is covered by the persistent bract and bracteoles. This type is called **Caryopsis.**

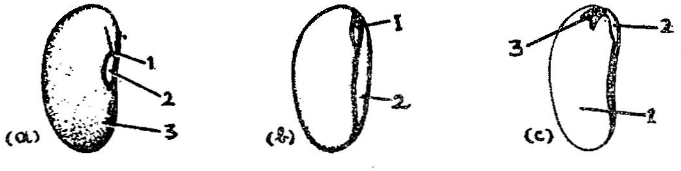
In *Pterocarpus*, the fruit is of the achene type but with a difference that is winged as the pericarp grows out as a

lateral expansion and this helps in making the fruit light so as to be easily carried away by the wind for dispersal. This type is known as **Samara.**

In *Cashew nut*, the fruit is of the achene type but of a big size and has a hard woody pericarp forming a **shell.** This type is known as **Nut.** The edible portion which is popularly known as fruit, is nothing but the swollen peduncle and tarus which have become succulent. That is the juicy portion of the cashew nut. So it is spoken of as a **pseudocarp** or **false fruit.**

The Seed

The fertilised ovule becomes the seed. The seed has two coats-the outer and the inner, named **testa** and **tegmen.** They are nothing but the two integuments of the ovules. In many



(a) External Appearance (b) Testa Removed (c) One Cotyledon removed.

1. Micropyle
2. Hilum
3. Seed coat

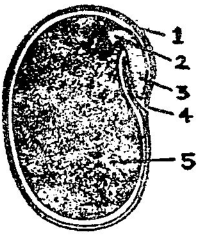
1. Cotyledon
2. Radicle
3. Plumule

Fig. 38

cases, the inner coat tegmen is fused with the testa. The embryo plant is the fertilised egg. The embryo sac has grown into a new storage tissue which is known as the endosperm. It serves to nourish the embryo plant.

Take a bean seed and soak it in water for a day. You can observe that the seed looks swollen, soft and heavier than when it was dry. You see a short longitudinal whitish ridge or scar. That is called the **Hilum** which is the portion of the seed that has been attached to the wall of the fruit. If you minutely observe, you can find a small opening at one end of the

ridge. Just gently press the soaked seed a little. You will see water coming out through that opening along with small air bubbles. The opening is called the **micropyle.** Remove the seed coat and you find two white fleshy cotyledons which look like leaves in their shape and size. They are called the open seed leaves. Open the cotyledons. You find a tiny plant in between cotyledons which is attached to the primary axis. The tip of the radicle is pointed towards the micropyle. When water enters through the micropyle, the cotyledons get swollen; the tiny plant gets awakened and the radicle starts growing out through the micropyle and we see the tiny root first and say that the seed germinates. The cotyledons serve as the supplier of food necessary for the growth of the tiny plant inside.



L. S. of Seed

1. Testa
2. Plumule
3. Radicle
4. Micropyle
5. Cotyledon

Fig. 39

As the bean seed is having two cotyledons, the plant is called dicolyledonous plant. *Peas, groundnuts, castor, tamarind* are *dicotyledenous* plants or dicots. *Paddy, maize, wheat, palmyrah* and *coconut* are *monocotyledonous* plants or monocots.

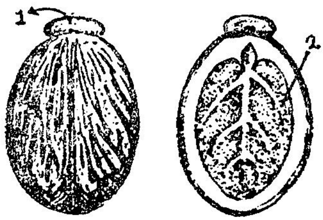
We have another classification among dicot and monocot seeds as some seeds have endosperm and others don't have. Seeds of the bean and the pea have no endosperm and hence are known as non-endospermous or exalbuminous seed. Seeds of paddy, wheat, dates, coconut have endosperm and hence known as endorspermous or albuminous seeds.

Nature of Endosperm

In the case of coconut and castor, plenty of oil is stored up in the fleshy endosperm.

In the date seeds, the endosperm is very hard and tough like ivory.

Examine the seeds of *Castor* and *Pithecolobium.* In castor you can find a peculiar kind of out growth at the micropylar end. It is hard white globular structure, covering the micropyle. It is the extra seed coat. It is known as caruncle.



Castor seed
1. Caruncle 2. Thin Cotyledon
Fig. 40

In pithecolobium seed, you can find that it is completely covered by a white spongy edible substance. It is called aril.

Dispersal of Fruits and Seeds.

In the case of dehiscent fruits, the dehiscence helps in the dispersal of seeds. But in the case of non-dehiscent fruits, the fruits themselves are dispersed by the agency of wind, water and animals.

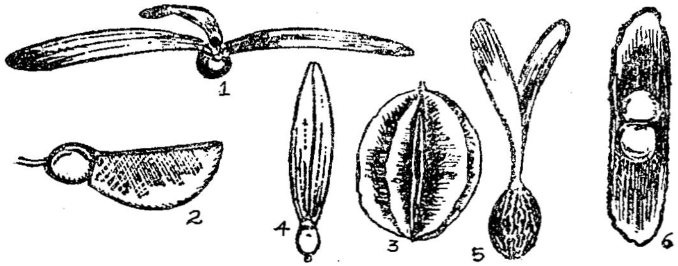
Dispersal of seeds and fruits are a necessity as otherwise all the seeds produced by the plants fall under the mother plant itself and when they germinate, there would be an extraordinary overcrowding as a result of which the soil will become less fertile very soon and there will be a struggle for existence for the numerous little plants as there will not be enough light and food.

Dispersal by Winds

The fruits and seed that are dispersed by wind have certain modification in order to facilitate easy carriage by wind.

Some fruits and seeds develop flat thin lateral expansion of wings. *Pterocarpus* and *Hiptage* are examples for winged fruits. In the case of seeds, the wings develop from the testa and are found all round the seeds in some plants and only on one side in some others.

In *Calotropis*, the seeds have tufts of hairs which help in floating in wind from one place to another like a parachute. In *Tridax*, the tuft of hairs is found on the top of the small fruits which is achene.



Dispersal by Wind

1. Hiptage 2. Pterolobium 3. Combretum 4. Ventilago 5. Gyrocarpus 6. Tecoma

Fig. 41

In *Clematis*, the style is feathery and helps in being carried by the wind.

In *Orchids* and *Poppy*, the size of the seed is so very small that they are scattered by the wind. This is a disadvantage in the wind dispersal as there is a large amount of wastage.

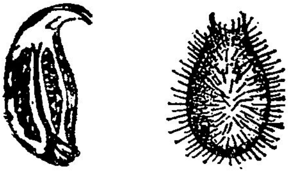
Dispersal by Water

Trees like coconut growing along the seashore and river banks take the help of water for dispersal of their fruits from one place to another. The pericarp of the *Coconut* has fibrous portion enclosing numerous air spaces. This makes the coconut light and enables it to float in water and it is carried away to long distance by rivers, waves and ocean currents. The dry fruits of *Casurina* are very light and float freely. In *Water lily*, the seeds are provided with a spongy aril and in *Lotus* the thalamus detaches and floats in water carrying the fruits.

Dispersal by Animals

The fruits that are dispersed by animals are provided with spines and hooks, which cling to the bodies of the animals

that brush against the plants. Two hooks are found in the fruit of *Martynia* and a number of hooks is seen over fruit of *Xanthium*. Sharp spines are seen on the fruits of *Tribulus* and they stick to the foot of animals and get dispersed from the mother plant.



Dispersal by Animals
Fig. 42

Some seeds which are coloured in a deceptive manner are carried by some birds which mistake them for insects. The seed of castor looks like a small beetle and is carried away by birds.

In *Margosa* and *Banyan* tree, fruits are swallowed by birds and the seeds are thrown out in the excreta. But no damage is done to the seeds as they are protected by hard coats. Ripe fruits like mango are carried away by squirrels and the seeds are dropped away from the mother plant after the edible portion is eaten.

Many fleshy fruits are eaten by man and seeds are thrown away. Hence man also helps in the dispersal of fruits and seeds.

Questions

1. What is a fruit?
2. Give two examples for simple fruit.
3. What are the different kinds of fleshy fruits? Give examples.
4. What are the two kinds of dry fruit?
5. What is a legume?
6. Give an example for a follicle.
7. Explain the different kinds of capsule with example.
8. What is an achene?

9. Is wheat an achene ?

10. Give an example for samara.

11. Why is cashew nut called pseudo carp ?

12. Describe the parts of a bean seed with the help of diagram.

13. What is the function of cotyledons and endosperm ?

14. Give examples for monocot and dicot seeds.

15. What is the nature of endosperm in date seed and coconut ?

16. What is caruncle ?

17. What are the differences between fruits dispersed by wind and water ?

18. What are the special adaptation that help the fruits to get dispersed with help of animals.

Do it Yourself

Collect different kinds of seeds and put them in small plastic bottles and label them.

Try to collect different kinds of coconut and also label them.

4. REPRODUCTION IN PLANTS

Sexual reproduction

We have seen that plants produce flowers which in turn produce fruits and seeds. When seeds germinate, we get new plants similar in all respects to the parent plant. This is called reproduction of the plant. Flowering plants reproduce through sexual process. The reproductive organ is the flower which has got the male and female sexual parts namely the stamens and the pistil. The nucleus in the pollen grain

coming out of the anther of the stamen is the male gamete and the egg found in the ovary of the pistil, is the female gamete and the fusion of the two is brought about by pollination and fertilisation. The gametes have all the qualities of the parents and hence it develops into a seed which is nothing but a tiny plant, a reproduction of the parent plant. When the seed germinates, the tiny plant grows. It takes root and gradually puts forth more leaves and with the help of these starts manufacturing its own food material, the carbohydrate, and grows independently. The child is a reproduction of man. The seed is a reproduction of the flowering plant. In non-flowering plants like algae and fungi, the gametes, though similar in size, are not differentiated with male and female and the fusion of such gametes give rise to the zygote which germinates into a new plant.

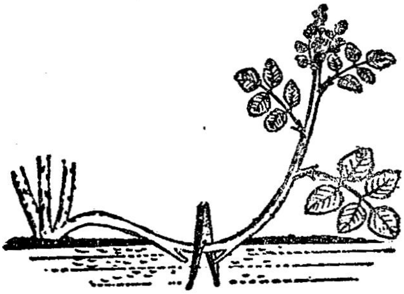
Vegetative Reproduction

Not all flowering plants succeed in reproducing through flowers. Some plants, though they produce flowers, are unable to produce seeds. Such plants reproduce through vegetative method. This is called vegetative reproduction.

Plantain trees reproduce not through the seeds, that we find in plantain fruit, but through the **rhizome** or the underground stem in which food is stored. Buds are put forth in the rhizome and they develop into small plants. They take the food from the rhizome and hence they are called **suckers**. Similarly in ginger and turmeric, the buds in the rhizome develop into new plants. In *Colacasia,* the buds in the corn, as in other forms of rhizomes develop into new plants. In *onion* and *garlic*, the bulbs are used to bring forth the new plants.

Flowering plants like *rose*, *nerium* and the different varieties of *jasmine* and *mullai* are propagated by the method of **layering** and not through seeds.

Select a mature branch of jasmine and bend it and fix it in the soil at the node portion and water it regularly.



Layering—Rose

Fig. 43

Roots develop at the node in few days. When they get fixed deeply in the soil, cut off the connectives of the branch from the parent plant. This cut branch will grow into an independent plant.

In *Bryophyllum*, the leaves are thick and succulent. They give rise to adventitious buds at the margin. If the leaves fall down on the soil, roots grow from the bud points and get the little plants fixed to the soil and then they grow independently.

Grafting is a method of vegetative reproduction. This method is used for producing better varieties of fruits like *mango, apple, grapes* etc. Grafting consists in making the lower portion of the cut plant unite with the upper portion of another which is rooted to the soil. The two plants unite and grow as one plant. The plant which retains its root is known as the **stock** and that which fuses with it, is called the **graft**. It is a cutting from another plant. There are three kinds of grafting.

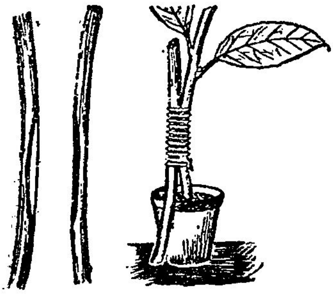
1. Approach grafting

2. Scion grafting

3. Budding

Approach Grafting

Grafting is done in this method by bringing two stems of different plants together, after cutting a small slice on the side. They are held firmly in position by tape. After a few months the organic union will be complete. The top of the stock and the base of the scion are cut off above and below the region of fusion respectively and the scion is left growing with the stock. This type of grafting is largely practised for propagation of *mangoes, sapotas* and *guauas*.



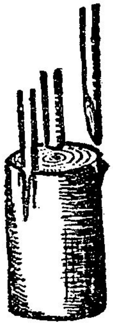
Approach Grafting
Fig. 43 (a)

Scion Grafting

The stem of a cut branch of the scion is fixed on the cut end of the stock in various ways. When the stock and scion are nearly equal in size and thickness, the stems are cut obliquely and the cut surfaces are brought together. Then bandaging is done with tape and to cover the bandage wax or clay is used.

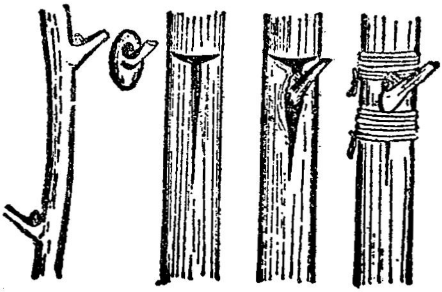
Budding or Bud Grafting

A '*T*' shaped incision is made on the stem of the stock and the bark is pried loose. A bud is taken out of the scion with a little wood and the same is placed in the incision beneath the bark and bandaged with tape to hold it in position. This method is mostly used for propagation of *apples, oranges, roses* and other ornamental plants. Grafting is used for producing



Scion Grafting
Fig. 43 (b)

better varieties of fruits and flowers. This is possible only between closely related plants.



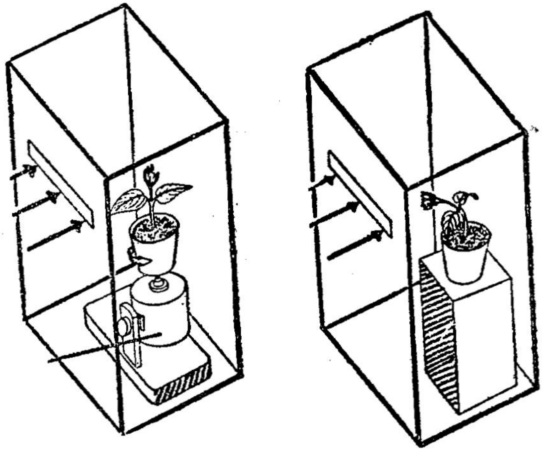
Bud Grafting
Fig. 43 (c)

Cutting

Sugarcane, drumstick and *crotons* are largely propagated by cuttings. A branch is cut below a node and is planted in the soil. It develops roots and becomes an independent plant.

Tropism

Growth movements in plants in which the direction

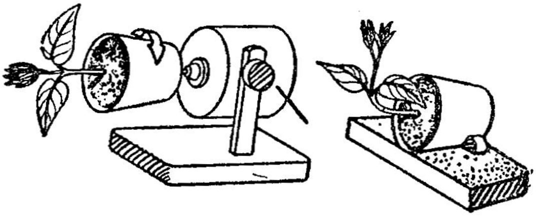


Positive Phototropism
Fig. 44

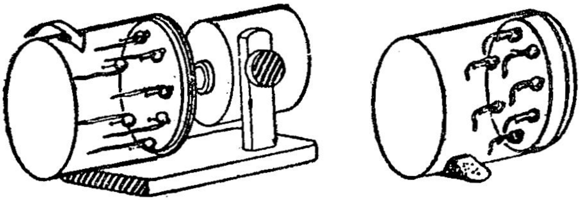
of growth is related to the direction of stimulus are called tropism.

The tendency to grow in response to the direction of light is called **phototropism** and the shoot is positively phototropic because it grows towards the direction of the stimulus-light.

The tendency of the shoot to grow away from the direction of the gravitational pull is **negative geotropism** and the tendency of the radicles to grow towards the gravitational pull is **positive geotropism.**



Negative Geotropism
Fig. 45



Geotropism in Root
Fig. 46

The radicles respond positively to the direction of water by growing towards it. This tendency is called **hydrotropism.**

Germination

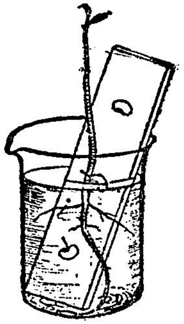
Germination is awakening into activity of the dormant embryo plant situated inside the seed.

The seeds as soon as they come out of the fruit are incapable of germinating. They need a period of rest.

Three conditions are to be satisfied for proper germination of seeds. They are (1) sufficient water (2) sufficient aeration and (3) certain amount of warmth.

Three Bean Seed Experiment

Take three bean seeds and fix them on to a cork pad with pins one at either end and one in the middle. Keep them in water kept in a beaker in such a way that the middle one is half in and half out of water. Leave the seeds in this condition for a day or two and observe what happens. The seed outside does not germinate. The seed in the middle germinates normally. The seed completely submerged in water tries to germinate by developing a small root portion without any further development.

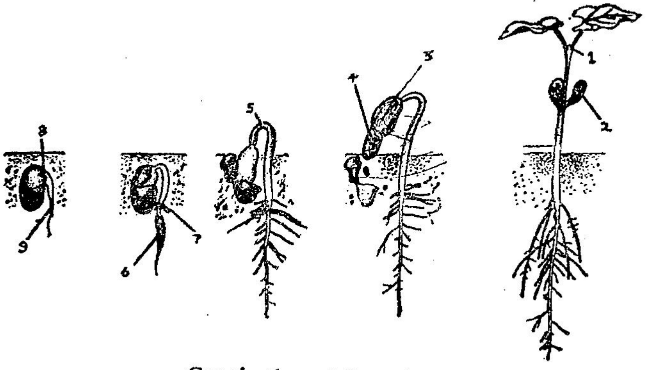


Requirements for Germination

Fig. 46 (a)

The seed outside gets sufficient aeration and warmth but gets no water. Hence no sign of germination.

The seed fully inside the water gets sufficient water and warmth but very little oxygen. So it germinates a little and then stops.



Germination of Bean Seed

1. Growing point 2. Cotyledons will fall off
3. Cotyledons withdrawn from the soil
4. Plumule protected between cotyledons
5. Hypocotyl "elbows" out of the soil
6. Root Hairs 7. Lateral Roots
8. Testa splits 9. Radicle emerges

Fig. 46 (b)

The middle seed has not only a good supply of water and warmth but sufficient air and so it germinates normally.

After germination the food materials stored up in the endosperm or the cotyledon are utilized for growth.

The radicle elongates and the first primary root is formed.

The plumule develops and leaves appear. Leaves start preparing their own starch with the help of sunlight and help in further growth.

Questions

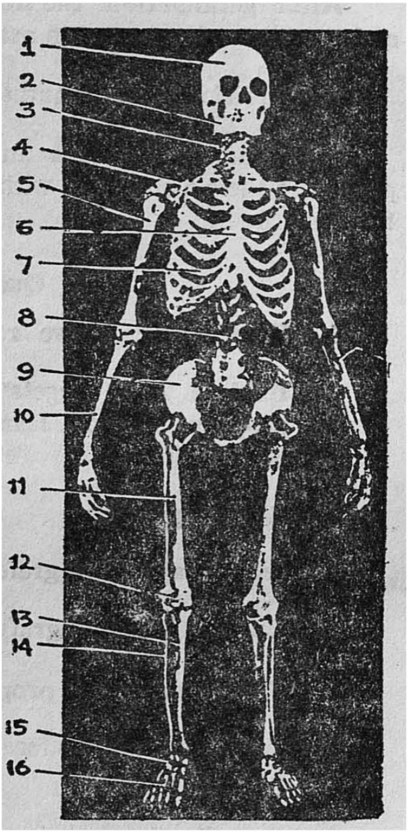
1. What is vegetative reproduction?
2. Explain how vegetative reproduction helps in the propagation of Jasmine, Plantain, Onion and Bryophyllum.
3. What is grafting?
4. What is approach grafting?
5. Explain how bud grafting is done.
6. How is sugarcane propagated?
7. What are the different kinds of tropisms seen in plants?
8. Describe the three bean seeds experiment.

5. THE HUMAN SKELETON

Vertebrate animals and man have bony skeletons within their bodies. The skeleton is the bony frame work of the body. It gives a definite shape to the body. Many bones of the skeleton act as levers. They produce a variety of movements such as flexing of the arms, chewing action of the jaws and the breathing movements of the ribs. It helps locomotion which is the result of the coordinated

action of the muscles on the limb bones. Movements of the skeleton are made possible by a system of joints and muscle attachments.

Skeleton has a protective function too. Certain delicate and very important organs of the body such as the brain, the heart and the lungs are supported and protected by a casing of bones. The brain is enclosed very securely in the skull. The spinal cord is in the backbone and the lungs are surrounded by a cage of ribs between the sternum and the spine. This casing and caging protect the organs from distortion resulting from pressure or injury resulting from impact. The rib cage besides protecting the heart and the lungs, plays a very important part in the breathing mechanism.



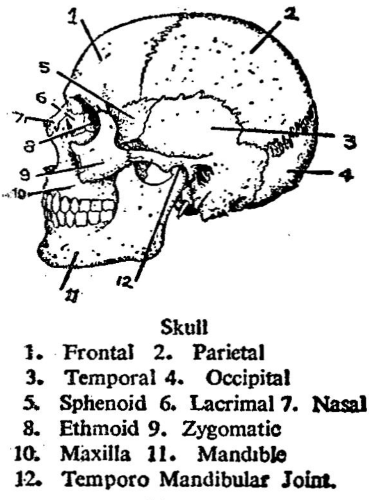
Human Skeleton

1. Skull 2. Lower Jaw 3. Neck Vertebra 4. Clavicle 5. Humerus 6. Sternum 7. Rib 8. Lumbar vertebra 9. Pelvis 10. Radius 11. Femur 12. Patella 13. Tibia 14. Fibula 15. Tarsals 16. Metatarsals 17. Radius and Ulna.

Fig. 47

Bones of different types and shapes are found in the human skeleton—flat bones, long bones, short bones, curved bones and irregular bones. They often have projections or ridges where muscles are attached. Where two bones meet, a joint is formed. The joints may have movement as in the leg, hand and spine or may not have movement as in the sutures between the bones of the skull. Muscles usually act across joints in such a way that the bones are worked as levers with

a low mechanical advantage. Muscles can only contract and release. But they cannot lengthen of their own accord. They have to be pulled back to their original length. To have this done, most muscles work in pairs. If one produces movement in one direction, the other does it in the opposite direction. Of such pairs of muscles, one is usually much stronger than the other. Locomotion is brought about by the coordinated movement of limbs by sets of antagonistic muscles contracting and releasing alternatively. But when the body is at rest, both the antogonistic muscles remain in a state of tension and hold the body in position.



Skull
1. Frontal 2. Parietal
3. Temporal 4. Occipital
5. Sphenoid 6. Lacrimal 7. Nasal
8. Ethmoid 9. Zygomatic
10. Maxilla 11. Mandible
12. Temporo Mandibular Joint.

Fig. 48

The skeleton can be divided into two parts, the **axial skeleton** and the **appendicular skeleton.**

The axial skeleton comprises the head and trunk and includes the following bones :-

Skull, vertebral column, sternum, ribs.

The appendicular skeleton comprises the upper and lower limbs and limb girdles.

In addition to the above, there are three small bones in each middle ear.

The Skull : The skull is the bony framework of the head arranged in two parts :- (1) the **cranium** and (2) the **facial skeleton.**

The cranium consists of eight bones. The cavity of the cranium presents an upper surface known as the vault of the skull. This is smooth in its outer surface and marked by ridges and depressions as it accomodates the brain and its blood vessels on the inner surface. The lower surface of the cavity is known as the base of the skull. The base is perforated by many holes for the passage of nerves and blood vessels.

The following are the cranial bones which are eight in number :

Frontal (1), Parietal (2), Occipital (1), Temporal (2), Sphenoid (1), Ethmoid (1).

The frontal forms the forehead. Its inner surface is marked by depressions which are produced by the convolutions of the brain. The two parietal bones together form the roof and sides of the skull. Though the outer surface is smooth, the inner surface is marked by deep furrows which lodge the cranial arteries. The occipital bone is at the back and lower part of the cranial cavity. It is pierced by the **foramen magnum** through which the medulla oblongata passes to join the spinal cord. Each side of the foramen magnum are masses of bone which form the condyles of the skull and present articulating surfaces for the **atlas**.

The temporal bones form the lower part of the sides of the skull.

The ethmoid is a light spongy bone, cubical in shape, situated at the roof of the nose.

The sphenoid is similar in shape to that of a bat with wings out-stretched. It consists of a body and two big and two small wings. The body shows a depression which lodges the pituitary gland. It lies at the base of the skull and forms a large part of the middle cranium.

The bones of the skull are united together by immovable joints called sutures with the exception of one of the bones of the face, mandible or the lower jaw which articulates with the temporal at the mandibular joint.

While at birth, in the skull of a child, a diamond shaped 4 cm. space from back to front can be seen at the junction of the frontal and two parietal bones which is filled in by a membrane and hence forms a soft spot. on the head. The pulse can be felt by touching the spot.

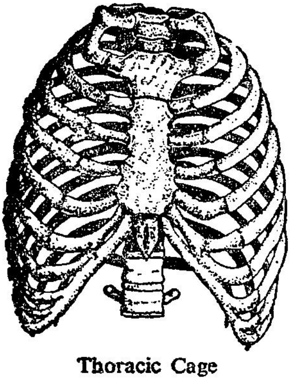
Bones of the Face: There are 14 facial bones, united by sutures and immovable except the mandible.

The bridge of the nose is formed by two nasal bones. Two palatine bones form the roof of the mouth and the floor of the nose. Two lacrimal bones form the tear ducts and through which the fluid from the eye is carried to the nasal cavity. The two molar bones with zygomatic process of the temporal bones form the temple area.

One vomer forms the lower part of the bony partition in the nose. The two maxillary bones form the upper jaw and contain the upper teeth. The mandible forms the lower jaw and contains the lower teeth. It is the only movable bone in the skull.

The Thoracic Cage

The skeleton of thorax is made up of bones and cartilages. The thorax is a cone shaped cavity, broader below than above and longer behind than in front. It is formed by the sternum in front and the twelve thoracic vertebrae at the back and the twelve pairs of ribs at the sides which encircle the trunk from the vertebral column behind to the sternum in front.



Thoracic Cage
Fig. 48 (a)

The sternum is the flat breast bone in the shape of a small sword. The upper seven pairs of ribs are attached to the sternum anteriorly by means of their costal cartilages. These are the true ribs. The first rib is the shortest.

The 8th, 9th and 10th ribs are attached indirectly to the sternum by means of the attachment of their costal cartilages to the cartilage of the rib above. The last two pairs of ribs are unattached in front and so are called the floating ribs.

The ribs slope downwards from back to front. The posterior end of the rib is more fixed than the anterior end which is more movable.

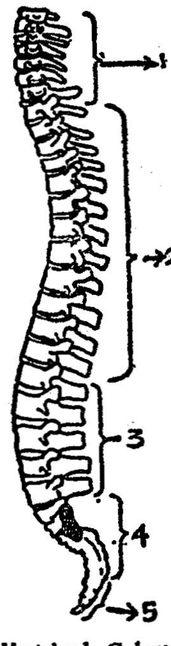
The spaces between the ribs are filled in by the intercostal muscles—external and internal.

The Vertebral Column : This is a flexible structure formed by a number of bones called vertebrae. Between two bones pads of fibrocartilage is found. This column measures 60-70 cm. in an adult.

There are 33 vertebral bones and 24 of these are separate bones and the remaining 9 vertebrae are fused to form 2 bones.

The vertebrae numbering 7 found in the neck region are called **cervical vertebrae.** The 12 **thoracic vertebrae** form the back of the thorax. In the region of the loins, there are 5 vertebrae. They are the **lumbar vertebrae.** Five **sacral vertebrae** form the sacrum. The four vertebrae that form the tail are called **coccygeal vertebrae.** This develops into tail in animals.

The twenty four vertebrae found in the upper regions of the neck, thorax and lumbar regions remain separate throughout life and are called **Movable Vertebrae** and the last nine vertebrae found in the lower regions, sacrum and coccyx are united in the adult to form two bones which are called the **fixed vertebrae.**



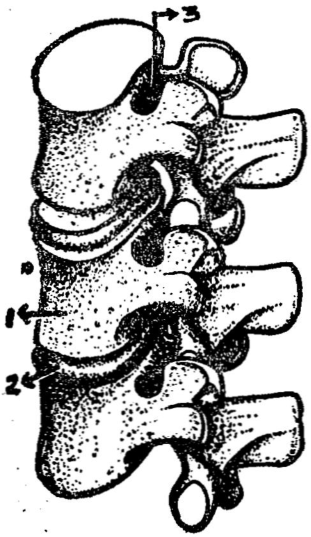
Vertebral Column
1. Cervical
2. Thoracic
3. Lumbar
4. Sacral
5. Coccygeal
Fig. 49

A typical vertebra has two parts – an anterior part, called **the body** and a posterior part called **the Neural-arch** enclosing the neural canal through which the spinal cord passes.

The Thoracic Vertebrae

They are larger than the cervical and also increase in size as they extend downwards. The body of the vertebrae is heart

shaped with facets on each side for attachment of the ribs. The neural arch is relatively small. The spinous process is long and directed downwards. The transverse processes which help to support the ribs are thick and strong and have articular facets for the ribs.



Vertebra in the Vertebral column

1. Vertebra
2. Disc of Cartilage
3. Spinal Canal

Fig. 50

The Lumbar Vertebrae are the largest. The body is very large and is kidney shaped. The spinous process is broad and hatchet shaped. The transverse processes are long and slender. The fifth lumbar vertebra articulates with the sacrum at the lumbar sacral joint, a typical intervertebral joint. The sacrum is a triangular bone situated at the lower part of the vertebral column. The sacral canal lies below the spinal canal and is a continuation of it. The walls of the sacral canal are perforated for the passage of the sacral nerves. The apex of the sacrum articulates with the coccyx.

The **coccyx** is composed of four or five rudimentary vertebrae fused to form one line. It articulates above with the sacrum.

The vertebral column presents, four anterior, posterior curves when looked at from side — the cervical curve in the neck region convex forwards, the thoracic curve converge backwards, the lumbar curve again convex forwards and the pelvic curve convex backwards.

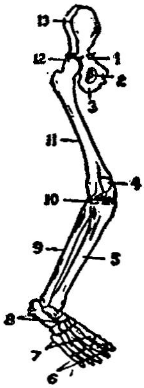
The vertebral column acts as a firm support to the body yet at the same time enable it to bend without breaking by means of its intervertebral discs of cartilage and its curves.

which give flexibility. These discs serve to absorb shock set up when moving the weight of the body as in running and jumping and thus helps to protect the brain and the spinal cord from shocks and jolts.

The vertebral column also supports the weight of the body and affords surfaces for attachment of muscles and ribs to form the thorax cavity.

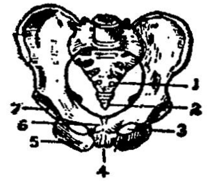
Pelvic Girdle

The pelvic girdle is the means of connection to the lower limbs, the legs. This is formed by part of the axial skeleton the sacrum and the coccyx being wedged in between the two



The Hip bone and the Bones of the Leg

1. Pubis
2. Obdurator Foramen
3. Ischium 4. Patella
5. Tibia 6. Phalanges
7. Meta Tarsals
8. Tarsals 9. Fibula
10. Knee 11. Femur
12. Hip Joint 13. Ilium.



2. Pelvis-Front View
1. Sacrum
2. Coccyx
3. Obdurator Foramen
4. Pubic Symphysis
5. Ischium
6. Pubis
7. Acetabulum Socket

Fig. 50 (a)

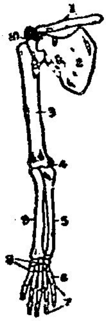
innominate bones which are named Ilium. The articulation between the articular surfaces of the ilium and the sacrum is called sacro iliac joint at which only slight movement is possible. At the region of pelvis, there is a joint between the

pubic bones which are separated by a pad of cartilage. The innominate bone is an irregular flat bone formed by the union of three bones at the acetabulum.

The Pectoral Girdle

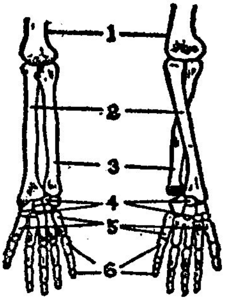
The skeleton of the upper limb is attached to the skeleton of the trunk by means of a girdle named the pectoral girdle. It consists of the clavicle and the scapula.

The clavicle or collar bone is a long curved bone forming the anterior part of the shoulder girdle. The clavicle provides attachment for some of the muscles of the neck and shoulder and thus acts as a prop to the arm.



Pectoral Girdle
1. Clavicle
2. Scapula
3. Humerus
4. Elbow Joint
5. Ulna
6. Metacarpals
7. Phalanges
8. Carpals
9. Radius
10. Shoulder Joint

Fig. 50 (b)



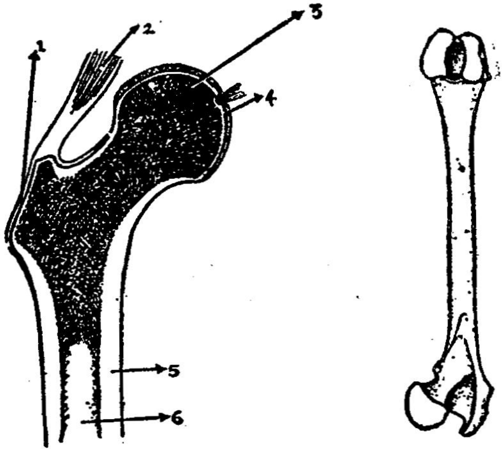
Bones of the Fore arm and Hand showing Supenation and Pronation
1. Humerus
2. Radius
3. Ulna
4. Carpals
5. Metacarpals
6. Phalanges

Fig. 50 (c)

The scapula forms the posterior part of the pectoral girdle. It lies at the back of the thorax superficially to the ribs. It is a triangular flat bone having a cavity called the glenoid cavity in which the head of the upper arm bone articulates.

Bones of the Lower and Upper Limbs

The thigh bone is the longest bone in the body and is known as femur. Its head articulates with the acetabulum and forms the hip joint. It is cylindrical, smooth, rounded in front and at the sides. It curves forwards and has a very well marked . ridge behind. The lower end is wide and has two condyles which are prominent. They are separated in front by the patellar surfaces on which the patella rests. The patella is a sesamoid bone. The apex of the patella points downwards. Its anterior surface is rough but its posterior surface is smooth and articulates with the patellar surfaces of the lower end of the femur. It lies in front but does not enter into the knee joint where the tibia, the leg bone joins with the femur.



The Thigh Bone-Femur

1. Periosteum 2. Tendon 3. Spongy bone (red marrow) 4. Cartilage 5. Compact bone 6. Fatty marrow

Fig. 51

The upper end of tibia has two condyles which is the most expanded portion of the bone. The lower end of the tibia enters into the formation of the ankle joint. The front of the tibia is smooth and tendons, passing to the foot, glide over it. The tibia articulates with three bones the femur, fibula and talus.

The fibula is the lateral bone of the leg. It is a long bone whose upper end articulates with the back of the outer condyle of the tibia but does not enter into the formation of the knee joint. Being slender, it is deeply embedded in the muscles of the leg to which it gives numerous attachments.

Bones of the Foot : The **talus** forms the central and highest point of the foot. It supports the tibia.

The **calcaneum** is the largest bone of the foot. It lies at the back of the foot forming the heel, transmitting the weight of the body to the ground posteriorly. It gives attachment to the large calf muscles through the tendons of achilles. It articulates with the talus above and with the cuboid in front.

Between the talus and the three small bones (**cuneforms**) is the navicular bone, a boat shaped one. All the seven short bones are together called tarsus which support the weight of the body when standing. Next comes the five metatarsal bones. The first metatarsal is thick and short and the second is the largest. Then comes the phalanges similar to those of the fingers but these are much shorter. There are four arches present in the foot. The bones of the arches of the foot are held together by ligaments and supported by muscles. These arches are maintained by the close adaptation of the bones, by the ligaments of the foot and by muscular action particularly by the muscles attached to the front and back of the tibia. The total number of bones found in the upper and lower limbs and their names are given hereunder:

Upper Limb		Lower Limb	
Humerus	1	Femur	1
Radius	1	Tibia	1
Ulna	1	Fibula	1
Carpal bones	8	Patella	1
Metacarpals	5	Tarsal bones	7
		Metatarsal bones	5
Phalanges	14	Phalanges	14
Total	30	Total	30

Joints and Ligaments

A joint is the union of any two or more bones of the skeleton. There are three types of joints namely fibrous, cartilagenous and synovial joints. These may be classified according to their mobility - immovable, slightly movable and freely movable.

Fibrous joints are immovable or fixed joints in which no movement between the bones is possible.

1. **Suture joints** in the skulls are joints of flat skull bones.

2. **Peg and Socket joints** - teeth in their sockets.

3. **Sindesmosis** - a joint where the articulating surfaces are connected by membrane as in the inferior tibilo fibular joints.

Cartilagenous joints are slightly movable joints in which the joint surface are separated by some intervening cartilagenous substance and only slight movement is possible, (eg.) 1. Intervertebral joints with their intervertebral discs of fibrous cartilage. 2. The pubic symphyses where a pad of cartilage unites two cubic bones. 3. The joint between manubrium, the triangular shaped piece of bone of the sternum and the body of the sternum.

Synovial joints are freely movable joints having the following characteristics:

1. The ends of the two bones which enter into the formation of the joint are covered by hyaline cartilage.

2. Ligaments are found binding the bones together. They are a kind of thin elastic but tough connective tissue layers. The movable joint is enclosed in a capsule. The joint capsule is a thin, tough connective tissue layer formed partly of the periosteum which continues a cover over the joint from one bone to the next. On the inner surface of the capsule is the synovial membrane, a layer of cells that secrete the synovial fluid to provide lubrication for the moving parts of the joint.

Kinds of Synovial Joint

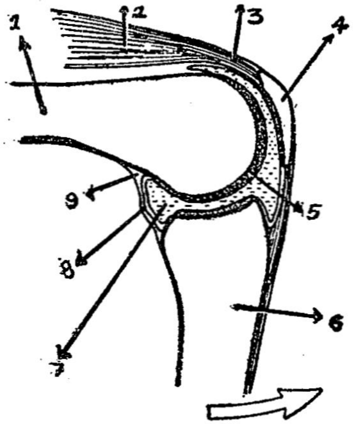
(1) Ball and Socket Joint

In this joint one rounded end of a bone fits into a cavity of another bone, permitting movements in all directions, as in

a ball within a socket or cup shaped cavity eg. the shoulder joint and the hip joint.

(2) **Hinge Joint**

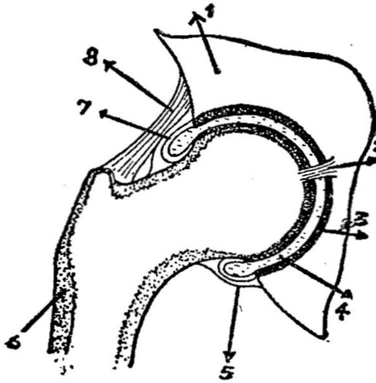
In this kind of joint, one rounded surface of a bone is received into another in such a way that movement is only



Hinge Joint of Knee

1. Femur 2. Muscle
3. Tendon 4. Patella
5. Cartilage 6. Tibia
7. Synovial Fluid
8. Synovial Membrane
9. Capsule.

Fig. 52 (a)



Ball and Socket Joint-Hip

1. Pelvis 2. Ligament
3. Cartilage 4. Synovial Fluid
5. Capsule 6. Femur
7. Synovial Membrane
8. Ligament.

Fig. 52 (b)

possible in one plane as occurs in the movements of a hinge. Elbow joint is the best example for this type of joint.

A. Atlas
1. Ring 2. The part where skull rests
3. Spinal Canal

B. Axis
1. Axis 2. Spinal Canal

Fig. 52 (c)

(3) Pivot Joint

In this joint, rotation is possible as in the movements of the head, where the ring like atlas, on which the skull rests, rotates round the peg shaped process of the axis. [Fig 52 (c)]. Another example is seen in the movements of the radius on the ulna in pronation and supination of the forearm. Pronation is rotation of the radius on the ulna until the hand lies palm down wards; supination is the opposite movement.

(4) Gliding Joint

In this joint, the flat surfaces of the two bones glide on each other (e.g) the joints of the carpus and the tarsus, the bones in the ankle part of the foot.

The Shoulder Joint

It is a synovial joint of the ball and socket variety. The head of the humerus forming one third of a sphere articulates within the glenoid cavity of scapula, the shoulder bone. The cavity is deepened by the attachment of fibre cartilagenous rim. The bones are united together by ligaments which form a very loose capsule. The loose capsular ligament allows free joint movement in all directions. The capsular ligament is lined with a thin membrane called the synovial membrane. The space surrounded by the synovial membrane is called the synovial cavity and the oily fluid secreted by it is called the synovial fluid which acts as a lubricant, lessening friction during movement of the limb. The capsular ligament and the synovial membrane together are called the capsule of the joint.

The Hip Joint

It is also a synovial joint of the ball and socket variety. The cavity in the hip bone, called the acetabulum, is deeper than the cavity found in the shoulder bone. The ligament which is in the nature of a rim of fibro-cartilage deepens and increases the adaptability of the surface to form an end cavity for the reception of the head of the femur, the thigh bone.

The capsular ligament limits the movement of the joint in all directions. The ligament is also specially strengthened by bands of fibres in several parts. These bands lie in front of the joint which limits extension at the joint and so help to

maintain the erect position in standing. This is the most important function of these bands.

The movement of this joint is not as free as we find in the shoulder joint.

The Knee Joint

The knee joint is modified hinge joint formed by the lower end of the thigh bone or femur and the upper end of one of the leg bones, tibia. There is a smooth surface at the end of the femur called the patellar surface on which lies the patella, the knee cap. It glides during movements of the joint. It lies in front of the knee joint and does not enter into the formation.

On the articular surfaces of the tibia are placed the semilunar cartilages on which the articular surfaces of the femur rest. Strong ligaments pass from the top of the tibia and to the rough surfaces of the femur. These limit the movement of the knee joint and bind the bones more firmly together.

The capsular ligament is extensive and considerably strengthened by expansion from the muscles and tendons which surround and pass over the joint. The synovial membrane of the knee joint is the largest in the body. In addition to lining the joint structure, it extends upwards and downwards beneath the ligaments of the patella and joins several bursals about the joint. The movements of the joint is flexion and extension and slight medial rotation. The ankle joint is also a hinge joint, formed by the lower end of the tibia and the lateral end part of the fibula which together form a socket to receive the body of the talus which forms the central and the highest point of the foot.

The capsule of the joint is strengthened by additional important ligaments. The joints between the tarsal bones are gliding joints as formed between carpal bones which form the wrist.

Question

1. What is a skeleton?

2. What are its functions?

3. What do the axial skeleton and appendicular skeleton comprise of?

4. Which are the cranial bones?

5. How many bones are there in the face?

6. Describe how the thoracic cage is formed.

7. How many bones are there in the vertebral column?

8. Compare the cervical and thoracic vertebrae.

9. Describe the lumbar vertebrae.

10. What is coccyx?

11. How does the vertebral column help our body?

12. Compare the pelvic girdle and the shoulder girdle.

13. Name the bones in the leg and the hand.

14. Name the bones of the foot.

15. What are the different kinds of joints?

16. Explain how movement occurs in a ball and socket joint.

17. What are the differences between the shoulder and the hip joint?

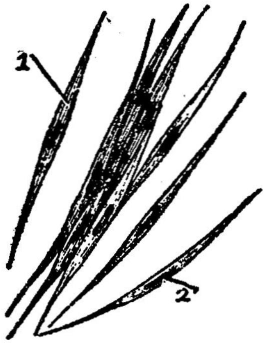
6. MUSCULAR SYSTEM

Muscle is a tissue which is specialized for contraction and by means of this, movements are performed. It is composed of cylindrical fibres which correspond to the cells of other tissues. These are bound together into little bundles of fibres by a form of connective tissues which contains a highly specialised contractible element.

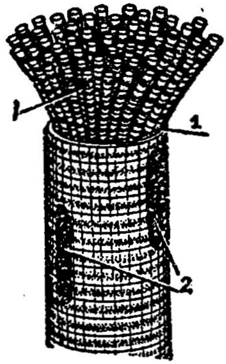
There are three types of muscles 1. Striped. 2. Unstriped and. 3. Sphincter muscles.

Striped Muscle

Striped muscle is also called striated, skeletal or voluntary muscle as the individual fibres making it, are transversely striated by alternate light and dark marking. Each fibre is made up of a number of tiny protein "myo fibrils" and is enclosed in a fine membrane called the sarcolemma. When the muscle contracts, it shortens each individual fibre which takes part in the movement by contracting. This type of muscle contracts only when it is stimulated to do so by the nervous system. So it is called the **voluntary muscle.** Since this type of muscle is attached to bones, it is responsible for the movements of different limbs. Hence it is called the **skeletal muscle.** When movement occurs during contraction of this muscle the central portion or belly of the muscle becomes thickened while the two ends are brought closer. During shortening of the muscle, one end tends to remain fixed in position while the other end moves. Muscles that produce movement in directions opposite to one another are said to be **antagonists**; those that work together to accomplish a particular movement are **synergists.** Two muscles that bend the arm at



Non-Striated Muscle Fibre
1. Cell-substance 2. Nucleus
Fig. 53



Fasciculi of Striated Muscle
1. Fasciculus 2. Nucleus
Fig. 54

the elbow are synergistic with one another but both are antagonistic to a muscle that straightens the arm.

Unstriped Muscle

This type is also called unstriated, smooth and involuntary muscle. This variety is composed of elongated spindle shaped muscle cells which retain the appearance of a cell. Without the usual nervous stimulation, this type of muscle will contract. But its activity is controlled by the sympathetic nervous system. This type of mucle is found in the walls of the blood vessels, lymphatic vessels, digestive tract, trachea, bronchi, in the iris and ciliary muscle of the eye and in the muscle of the skin. This type of muscle is not attached to the bones.

Cardiac Tissue
A Microscopic view of Cardiac Muscle showing the Characteristic Branching of its fibres
Fig. 55

Sphincter Muscle

A sphincter muscle is composed of a circular band of muscle fibres situated at the internal or external openings of a canal or at the mouth of an orifice, tightly closing it when contracted. The internal sphincter in the opening from the bladder to the urethra, external sphincters of the anus, the pyloric sphincter at the openings of the stomach are examples.

Cardiac Muscles

It is striated like voluntary muscle and is found in the muscle of the heart. The fibres are arranged longitudinally as in striated muscle and characteristically are red in colour. But its movements are not controlled according to our will. Cardiac muscle possesses the special property of automatic rhythmical contraction, independent of its nerve supply. Normally the action of the heart is controlled by its nerve supply.

Muscle Tone : Muscle is never completely at rest. Though it may appear to be so, yet it is always in condi-

tion of muscletone, which means ready to respond to stimuli. Posture is determined by muscle tone. Muscle contracts more forcibly when it is stretched and when it is warm. Fatigue and cold weaken the powers to contract.

Tendons

Tendons are white, glistening inelastic fibrous bands which bind the muscle to the bone.

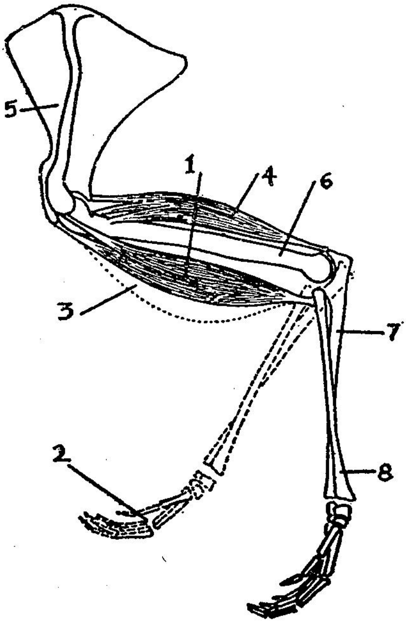
Muscles are attached to bone, cartilage, ligaments and to the skin.

Muscles which surround the trunk are broad and flat and those of the limbs are long. Muscles immediately placed beneath the skin are flat.

Any disease or disorder of the skeletal muscle is termed **myopathy**. Cramp is an involuntary, painful localized contraction of a muscle, which can be relieved by stretching the muscle. This may occur after vigorous exercise. Cramp is usually seen in the thigh or calf muscle. Skeletal muscles are usually attached to two definite points. The more fixed point is named the **origin** and the more movable part the **insertion**. The origin is considered to be the point from which the muscle arises and the insertion, the point to which the muscle passes. That point is the structure providing attachment which is to be moved by the particular muscle.

The movement of the forearm upwards serves as the best example. The large muscle that is in the front part of the arm the **biceps**, arise from the scapula, the shoulder bone and passes down the arm to be inserted into the radius of the forearm. The scapula is the more fixed point and the radius is the point moved by the biceps which is attached to the scapula by two tendons. It has a large belly but is not attached to the humerus. It gradually narrows down and passes into a tendon which is attached to radius.

Behind the humerus is another muscle named triceps attached to the scapula by three tendons. Its lower end is inserted to the upper end of the ulna by a tendon. The biceps and the triceps being antogonistic muscles, when one contracts the other releases. It is this antagonistic movement that helps in the raising and lowering of the forearm.



Flexion of the Forearm

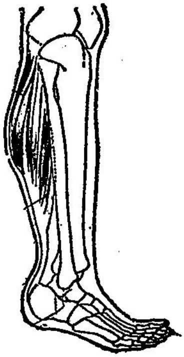
1. Biceps being normal 2. Lifting of the forearm
3. Biceps being bulged 4. Triceps becoming thin and long
5. Clavicle 6. Humerus 7. Ulna 8. Radius

Fig. 56

Another strong muscle which has a large belly is the calf muscle which is mainly responsible for movements like walking, running, jumping and standing. The tendon

that joins it to the heel bone is called the **tendon of Achilles.** When it contracts, the heel is pulled up, and raised and the foot is stretched.

Contraction of a number of muscles at the same time help the body to stand erect and maintain a steady position.



Calf Muscles
Fig. 57

Questions

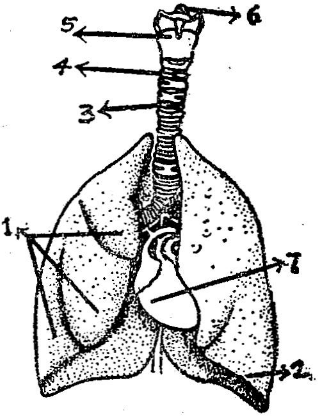
1. What is a muscle ?
2. What are the different types of muscles ?
3. Explain the nature and function of striped and unstriped muscles.
4. Where do we find the sphincter muscle in our body?
5. In what ways does the cardiac muscle differ from unstriped muscle?
6. What do you mean by muscle tone ?
7. What are tendons ?
8. How does cramp occur?
9. Explain with the help of a diagram, how the forearm is lifted and brought back to position.

7. THE RESPIRATORY SYSTEM

The lungs are the respiratory organs of man. They are two thin walled, soft elastic sacs lying in the thorax cage of ribs between the sternum and the spine. They are covered by membranous sacs called the **pleura.** They can be expanded or compressed by the movements of the ribs in the chest cavity in such a way that air is taken in and expelled repeatedly. They

are attached to the two branches of the wind pipe or **trachea** which opens into the **pharynx**, through which communication with the atmosphere is made possible.

The two branches of the trachea are called the **bronchi**. They enter the lungs and divide further into smaller and smaller branches. They are called **bronchioles**. They divide further and further and end in a mass of little thin walled pouch like air sacs which are called **alveoli**. The trachea is made up of rings of cartilage which keep the trachea and bronchi open and prevent their closing up when the pressure inside them falls during breathing in. The lining of the air passages covered with numerous **cilia** which are minute cytoplasmic hairs which constantly flick to and fro. Mucus secreted by glandular cells is also in the lining. Dust particles and bacteria in the air get trapped in the mucus film and swept away by the movements of cilia up the larynx and into the **pharynx** where they are swallowed. The **epiglottis** prevents large particles (food) from entering the air passage particularly while swallowing. Any foreign particle that accidentally enters is removed by choking and coughing, which are reflex actions.

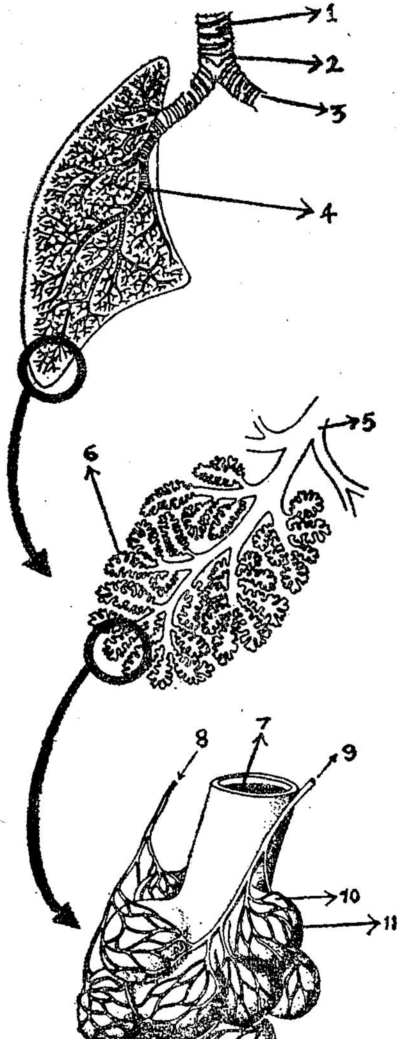


Lungs

1. Right Lung 2. Left Lung
3. Trachea 4. Cartilage Ring
5. Larynx 6. Epiglottis
7. Heart

Fig. 58

The alveoli or air sacs have thin elastic walls consisting of internally a single cell layer and beneath this dense network of capillaries. This network carries de-oxygenated blood from the heart through the pulmonary artery. In one human lung there are about 350 million alveoli with a total absorbing surface of 90 m^2.



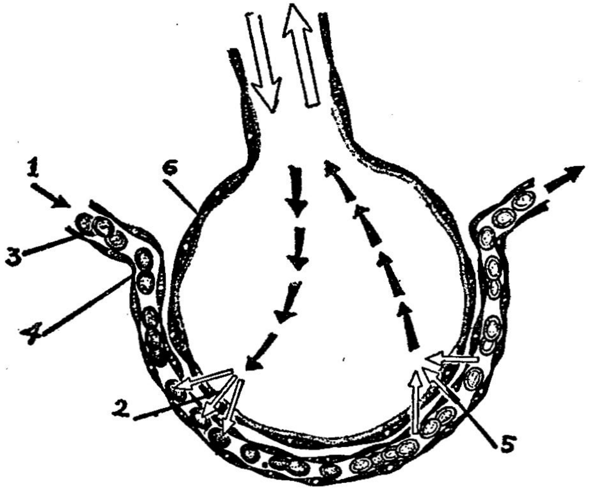
1. Ring of Cartilage
2. Trachea
3. Bronchus
4. } Bronchiole
5.
6. Alveolus
7. Air Passage
8. Pulmonary Artery
9. Pulmonary Vein
10. Alveolus
11. Capillary Network

Air Passages in Lungs

Fig. 59

Exchange of Gases

A film of moisture covers the lining of the alveoli. The oxygen concentration in the blood being lower than in the alveolus, oxygen in the air space dissolves in the film of moisture and diffuses through the epithelial layer, the capillary wall, the plasma and into a red cell. The capillaries reunite



Gaseous exchanges in alveolus

1. Air or Oxygen 2. Oxygen enters the red cell 3. Red cell
4. Capillary 5. Carbon-di-oxide enters the Alveolus
6. Epithelium of Alveolus

Fig. 60

and form the pulmonary veins which return the oxygenated blood to the left auricle of the heart. The low concentration of carbon-di-oxide in the alveoli stimulates the enzyme,

Content	Inspired air	Expired air
Oxygen	21%	16%
Carbon-di-oxide	0·04%	4%
Nitrogen	79%	79%
Water vapour	Varies	Saturated.

carbonic anhydrate in the blood to break down the hydrogen carbonate salts and liberate carbon-di-oxide. This gas diffuses into the alveoli and is expelled when we breathe out. The table in the previous page gives an idea about the approximate difference in the percentage composition of the inspired and expired air.

The breathing movements are rhythemic and take place quite unconsciously at the rate of 16 times a minute. They are controlled by the region of the brain which is very sensitive to carbon-di-oxide concentration in the blood. If there is any rise in carbon-di-oxide concentration, nerve impulses are automatically sent to the diaphragm and muscles which increase the rate and depth of breathing. During vigorous activity, more carbon-di-oxide is produced and to expel rapidly accumulating carbon-di-oxide and to increase the amount of oxygen into the blood, the rate of breathing is accelerated and the demands of increased tissue respiration is met.

The rate of breathing can be controlled voluntarily while sighing.

In an adult man, the fully inflated lungs have the total capacity of 5½ litres but during quiet breathing only about 500 cc of air is exchanged. This is called **tidal air.** During activity, deep inspiration we can take in another 2 litres and vigorous expiration can expel an additional 1½ litres. Another 1 litre can never be expelled. This is called the **residual air** which remains stationary in the alveoli. This exchanges carbon-di-oxide and oxygen by diffusion with the tidal air that sweeps into the bronchi and the air passages.

Mechanism of Breathing

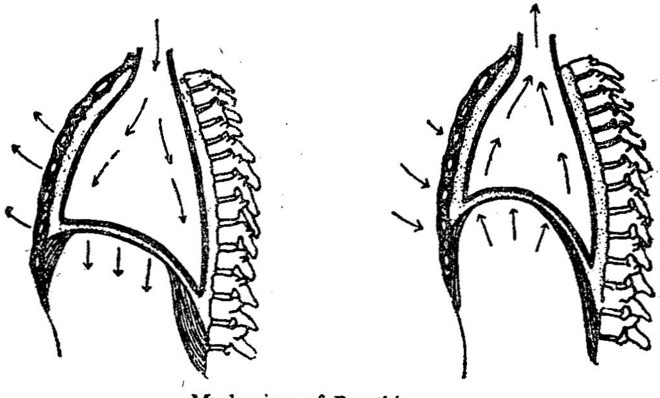
The thorax is an airtight cavity enclosed by the ribs at the sides and the diaphragm below. The diaphragm is a muscular sheet of tissues extending across the body cavity between the thorax and abdomen. While at rest it is dome shaped extending upwards into the thoracic cavity, with the liver and stomach immediately below it. If we change the volume of the thorax, the volume of the lungs which are too thin to oppose the movement is changed automatically.

Inspiration

The **intercostal muscles** run obliquely from one rib to the next. When these muscles contract, the lower ribs are raised upwards and outwards. This causes the volume of the thoracic cavity to increase and consequently the volume of the lungs increases. Its capacity is raised and pressure of air inside the lungs decreases and the air outside is forced into them through the nose and trachea by atmospheric pressure which is at a higher level. The same happens when the muscles of the diaphragm contract and causes it to flatten from its domed position.

Expiration

When the intercostal muscles of the rib and that of the diaphragm are relaxed, the ribs move down under their



Mechanism of Breathing

Inspiration Expiration

Fig. - 61

own weight and the organ, below the diaphragm, under pressure from the muscular walls of the abdomen, push the relaxed diaphragm back into its domed position. As a result of the movements, the lungs return to their original volume by virtue of their elasticity. Now the air containing more carbon-di-oxide and water vapour and less oxygen is expelled, because of the increase in pressure consequent on the reduction in volume of the lungs.

In quiet breathing, usually the movements of the diaphragm alone are responsible for the ventilation of lungs.

Questions

1. Describe the structure of the lungs with the help of a diagram.
2. How does the gaseous exchange take place in the alveoli ?
3. How do inspiration and expiration take place ?
4. What are the differences between inspired and expired air ?

For Thought

1. If air is injected into the pleural cavity, what will happen to the lungs ?
2. In man, gaesous exchange takes place in lungs. Do you know where it happens in insects, fish and frog?

Do it Yourself

Take clear lime water in a bottle. Blow some air bubbles into it through a straw for a minute or two.

Observe what happens to the clear liquid.

Can you guess the reason for the same ?

Continue blowing for some more time. Observe what happens and find out the reason.

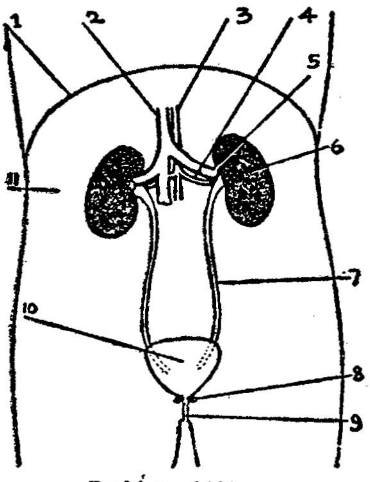
2. Take a large plastic bottle calibrated upto 5 litres by filling it with water, 1 litre at a time and mark the levels. Invert the bottle full of water in a trough or a bowl of water, remove the stopper and insert a rubber tube through the neck.

Then take a deep breath and exhale through the tube so that the exhaled air collects in the bottle displacing the water. The level of water left in the bottle will give a measure of the lung capacity.

8. EXCRETORY SYSTEM

Excretion is the process by which the harmful products of catabolism such as ammonia and other nitrogenous compounds urea, uric acid and carbon-di-oxide. The products of respiration are removed from the body as fast as they exceed a certain concentration.

In man, the important excretory organs are the kidneys and lungs. The kidneys excrete nitrogenous compounds, urea and uric acid from the blood and eliminate excess of water and salts. The lungs excrete carbon-di-oxide and water vapour.



Position of kidneys

1. Diaphragm 2. Vena Cava
3. Aorta 4. Renal Artery
5. Renal Vein 6. Left Kidney
7. Ureter 8. Sphincter Muscle
9. Urethra 10. Urinary Bladder
11. Abdomen

Fig. 62

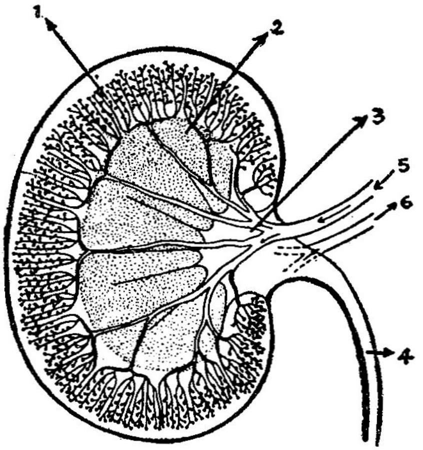
The Kidneys

The kidneys are two in number, fairly solid oval structures with a depression at the innermost sides. They are reddish brown in colour. They are attached to the back of the abdominal cavity

A longitudinal section through a kidney shows a darker outer region called **the cortex** and a lighter inner region called the **medulla**. Then comes the pyramids or cones of kidney tissue which project into a space called **pelvis**. From there starts the **ureter** which descends and joins the **bladder**.

The artery that supplies blood to the kidney is the renal artery. It divides up into a great many arterioles and capillaries mostly in the cortex. Each arteriole leads to a glomerulus which is a capillary repeatedly divided and coiled making a little knot of vessels. The glomerulus is

almost entirely surrounded by a cup shaped organ called Bowman's capsule which leads to coiled renal tubule. This tubule after a series of coils and loops joins inner tubules and passes through the medulla, to open into the pelvis at the apex of a pyramid.



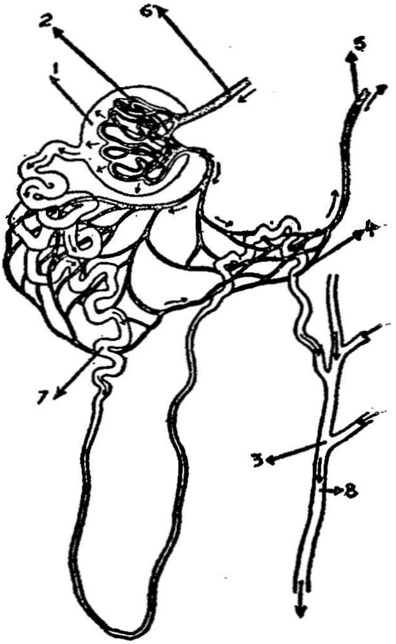
Kidney–Longitudinal Section

1. Medulla with network of nephrons 2. Pyramids
3. Pelvis 4. Ureter 5. Renal Artery 6. Renal Vein

Fig. 63

The capillaries of the glomerulus offer resistance to the flow of blood so that a high pressure is set up. This pressure makes the fluid to filter out through the capillary walls and collect in the Bowman's capsule. The filtered fluid is called the glomerulus filtrate. It contains glucose, salts like sodium chloride and nitrogenous waste dissolved in water but fibrinogen and other proteins remain in the blood. As the filterate passes down the renal tubule, all the glucose, some of the salts and much of the water are reabsorbed into a network of capilleries surrounding the tubules. The remaining liquid which is now called urine contains only the waste products such as inactive harmones, urea, excess salt and water. When this liquid passes

down the collecting tubule, more water is absorbed and the concentration of the blood is regulated.



Nephron

1. Bowman's Capsule 2. Glomerulus 3. Collecting Duct
4. Capillary network 5. Vein 6. Artery 7. Urinary tubule

Fig. 64

If the blood is too dilute as a result of drinking more water, less water is absorbed back into the blood and the urine is dilute. If the blood is too concentrated after sweating profusely, more water is reabsorbed from the collecting tubule making the urine more concentrated. From the collecting tube, the urine enters the pelvis of the kidney where it collects and and passes down the water to the bladder.

The capillaries from the glomerulus and the renal tubules join together to form the renal vein. The blood leaving the kidneys in the renal vein contains less oxygen and glucose

more carbon-di-oxide and less water; salts and nitrogenous waste is a result of extraction. The following table shows the percentage of certain nitrogen compounds present in the blood and in the urine :

Sl. No.	Waste Products	Percentage of nitrogen compounds in blood	Percentage of nitrogen compounds in urine
1.	Urea	0.03	2
2.	Uric acid	0.005	0.05
3.	Ammonium compound	0.0001	0.05

The urine collects in the bladder which is an extensible sac with elastic and muscular tissues in its walls. It can be extended to a volume of 400 cm^3 or more. At intervals, the sphincter muscles which closes the outlet to the bladder relaxes and the bladder contracts aided by the muscles of the abdomen, expelling the urine through a duct called **urethra**.

Questions

1. What is excretion?
2. Describe the structure of the kidney with the help of a diagram showing the longitudinal section.
3. What is glomerulus? Draw a diagram of urinary tubule and explain.
4. How is urine excreted?
5. In cold weather one may need to urinate frequently producing a fairly colourless urine. In hot weather urination is infrequent and the urine is coloured. Explain these observations.

Do it Yourself

Collect a kidney of the goat and dissect it longitudinally and draw its diagram indicating the various parts.

9. SKIN

Skin is a continuous layer of tissue over the surface of the body. It protects the tissues beneath from mechanical injury, bacterial infection, desiccation and ultraviolet rays in sunlight. It contains numerous sense organs which are sensitive to temperature, touch, pain and so make us aware of changes in our surroundings.

It plays a great part in keeping the body temperature constant.

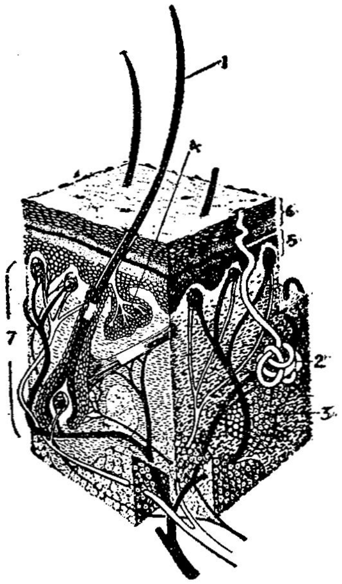
It also serves as an excretory organ in as much as it produces sweat and removes excess of water and salts mostly sodium chloride from blood.

Structure

The skin consists of two main layers (1) **outer epidermis** and (2) an **inner dermis.**

Epidermis: It consists of three layers, the **malphigian layer**, the **granular layer** and the **cornified layer.**

The malphigian layer is a continuous layer of cells which can divide actively and produce new cells and hence produce new epidermis. It is in this layer we find the pigment granule and melanin which determine the colour of the skin and act as a screen against ultraviolet light.



Section of the Skin

1. Hair
2. Sweat Gland
3. Fat Globules
4. Sebaceous Gland
5. Malphigian Layer
6. Epidermis
7. Dermis

Fig. 65

Next is the granular layer which contains living cells. But toward the outside it gives way gradually to the cornified layer.

In the cornified layer, we find only dead cells which form a tough outer coat which offers resistance to damage and invasion of bacteria. It also reduces the loss of water by evaporation. The cells of this layer are continually being worn away and replaced from beneath. This becomes thick on the palm of the hand particularly when the hands are used for the manual work and so also the soles of the feet.

Dermis

This is a thicker layer of connective tissue under the epidermis. It has many elastic fibres, blood capillaries nerve endings or sensory organs, lymphatic and sweat glands and hair follicles.

The blood capillaries supply the skin tissue with the necessary food and oxygen and remove its excretory products. These capillaries play a very important part in the control of body temperature. The sweat glands and hair follicles are surrounded by the capillaries.

Sweat Glands : Sweat glands are coiled tubes which consist of secreting cells which absorb fluid from the surrounding cells and capillaries and pass it into the sweat duct which take it up to the surface of the skin. The fluid which we call sweat contains water with some salts, largely sodium chloride, dissolved in it and also small quantities of urea and lactic acid. There are about 2 to 3 million sweat glands. The body loses water vapour fairly constantly at most normal temperatures. But these glands do not operate until the body temperature rises about $0{\cdot}2°C$ to $0{\cdot}5°C$ above normal.

Hair Follicle : The hair follicle is a deep pit of granular and malphigian layers. The cells there multiply and build up a hair inside the follicle. The cells of the hair becomes impregnated with a horny substance, **karatin.** The constant adding of new cells to the base of the hair causes it to grow. Growth continues for about four years; then the hair falls out and a new period of growth begins. The hairs of the body form a protective covering and heat insulating layer in the parts where they grow thickly. The layer of stationary air held between the hair reduces

evaporation and heat loss. The follicle is supplied with sensory nerve endings which respond to the movements of the hair. This sensory function of the hair is well developed in the whiskers that grow on the side of the face in mammals like the cat or the mouse.

The water repelling properties of hair is due to the only secretion produced by the sebaceous glands that open into the hair follicles. The same oily secretion is responsible for keeping the epidermis supple and reducing the tendency for it to become too dry as a result of evaporation. It also has antiseptic properties against certain bacteria. Fat cells are seen in large numbers in the layer beneath the dermis. Fat is stored in them. The fat also serves as a heat insulating layer.

Maintenance of Body Temperature

When body gets heated due to the heat rays of the sun, disease and vigorous physical activity like running or any other external cause, the blood temperature will tend to rise. Even if it is a fraction of the degree over normal temperature, when the blood reaches the brain, nerve impulses are at once sent to the skin and the arteries, that supply the capillaries beneath the epidermis dilate. That causes more blood to flow near the surface. As a result of that, more heat escapes into the air by convection and radiation. And the nerve impulses increase the rate of sweat production so that a continuous layer of moisture may be produced on the surface of the skin. As the sweat evaporates, the latent heat is absorbed. It reduces the temperature of the body. The evaporation is dried up only on movements due to breeze or fan as a result of which there is a cooling effect on the body. But when the air contains so much water vapour, the sweat may not evaporate rapidly enough to produce an adequate cooling effect and may lead to heart stagnation causing collapses and sometimes even death. Heat stroke or sunstroke is the result of over heating of the body system when, after prolonged sweating due to vigorous activity at high temperature, sweat production ceases and the body temperature rises to a death level.

In cold climatic conditions, there is a decrease in sweating which minimises heat loss by evaporation. The arterioles which supplies blood to the capillaries gets constricted and reduces the volume of blood flowing near the skin surface and hence diminishes heat losses. This constriction of arterioles make a person look pale blue.

When the body temperature begins to drop suddenly, one starts shivering. It is a reflex action. It is spasmodic contraction of muscles which produce heat which helps to raise the temperature of the body.

The skin and kidneys co-operate with each other in regulating the body temperature according to the climatic changes. In winter and rainy season, the kidneys work more and the skin does less work. In summer, the skin does more work and the kidneys do less work.

Because of the production of sweat, there is a great need to keep the skin clean by washing and bathing using soap. The dress also should be kept clean by regular washing.

Questions

1. What are the functions of the skin?
2. Describe the structure of the skin with the help of a diagram.
3. What are sweat glands and hair follicles?
4. How does the skin maintain the body temperature?
5. You may feel hot after exercise or feel cold without your overcoat and yet your body temperature is not likely to differ by more than 0·5°*C* on the two occasions. Explain this apparent contradiction.

Know Yourself

1. There is a fatty substance called ergostrol in the skin. This helps the skin to prepare vitamin D when sunlight falls on the skin.

2. People in western countries take sun bath only because they need vitamin D.

10 NERVOUS SYSTEM

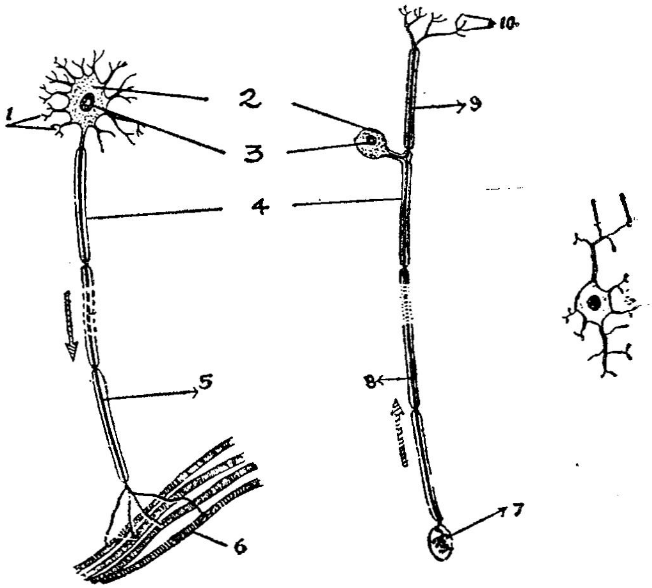
The skeletal system, the muscular system, the respiratory system, the digestive system, the circulatory system and the excretory system in man, though happen to have separate functions of the human body, only the total result of all of them cons-titutes the complete living organism in man. Although these physioloical systems or processes can be usefully considered individually, they are in fact all very closely linked and dependent on each other. The digestion of food is closely linked with blood circulation which absorbs and distributes the products of digestion. The circulatory system is linked with every other system, the respiratory, the excretory, the muscular and the skeletal.

All these systems must work together to have a harmonious action of the human body. The timing and location of one set of activities is closely related to the others.

Let us take the action of walking. While walking, the legs do not move at the same time. They move alternately. During exercise, when the body needs more food and oxygen, the breathing rate is automatically increased and the heart beats faster and sends a greater volume of oxygenated blood to the muscles. When we eat our food, the position of the food is recorded by the eyes and as a result of this information, our arms are moved to the right place to take it up, not by trial and error but with precision and accuracy. As the food is raised to the mouth by the hand, the mouth opens to receive it as fast at the right moment. Then starts the chewing movement and saliva is secreted. At the movement of swallowing, many things happen simultaneously. The gastric glands in the stomach begin to secrete enzymes to digest the food when it arrives there through the gullet. So we see that in the act of eating, many bodily functions come into action just at the right time.

The nervous system is a series of conducting tissues running to all parts of the body co-ordinating all the other systems.

The units which make up the nervous system are nerve c ells named **neurons.** These are small masses of cytoplasm



Nerve Cell

1. Denderites 2. Nerve Cell 3. Nucleus 4. Sheath
5. Axon 6. Muscle Fibres 7. Sensory Receptor in Skin
8. Dendron 9, Axon 10. Synaptic Knobs

Fig. 66

with a central nucleus. The cytoplasm has got one or more branching. Those filaments are called **dendrites.** They conduct impulses towards the cell body. A single long fibre of the cell body conducts impulses away. That is called an **axon.**

In sensory neuron, the single elongated dendrite is called a **dendron.** Dendrons and axons are collectively called **nerve fibres.** They consist of fluid filled cytoplasmic tubes, in certain cases, surrounded by insulating sheaths of fatty materials.

In mammals, it is found that the cell body is usually in the brain or spinal cord and the axon and dendrons extend the whole distance to the concerned organs. This may be for great lengths from the base of the spine down to the toe. The

nerve fibres have the special property of being capable of transmitting electrical impulses very rapidly down its entire length and then pass them then and thereon to the next nerve cell in line. There is a difference between the conduction of electricity in a metallic wire and that of the nerve fibre.

The axon builds up within itself an electrical charge. It is released when the nerve is stimulated. The axon has to build up an electrical charge again before the next impulse can pass. As nerve cells transmit impulses in one direction only, the dendron that carries the impulse from a sensory organ to the nerve centre, it is called a **sensory fibre, or sensory nerve** and if it passes from a nerve centre to a muscle or gland, it is called a **motor fibre or motor nerve.** The sensory nerves and the motor nerves are also called **afferent** and **efferent** nerves.

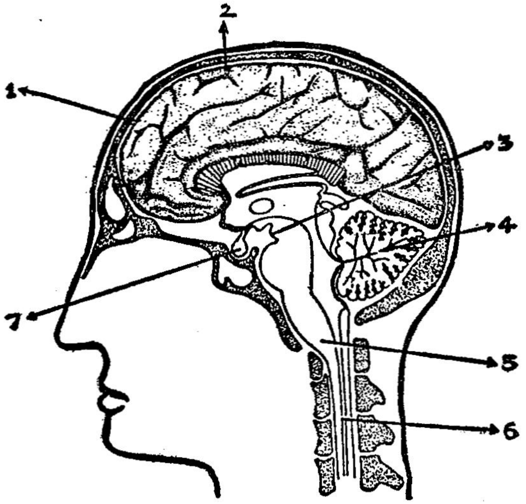
A nerve impulse passes from one nerve cell to another by means of a synapse. It is probably the basic computer unit of the central nervous system, making possible effective coordination. An individual cell body may have synapses with many incoming fibres and it is with the synapses that the different parts of the body and brain are kept in communication.

The grey matter of the brain and spinal cord consists of cell bodies and their synapses. In men and other vertebrate animals, the central nervous system consists of the brain and spinal cord. It is just like a telephone exchange which helps you to be placed in communication with any one in the country rapidly and effectively.

Some of the cell bodies lie in the central nervous system. Since all impulses from or to the body pass through it, it is possible to have a vast number of cross connections and linkages that could not arise if the nerves simply ran down from one organ to another. Nerves are bundles of fibres, the cell bodies of sensory fibres sometimes forming a bulge is ganglion in their length. Most nerves contain both motor and sensory fibres though one or other may predominate.

The Human Brain

The human brain is securely encased in the thick skull of man. The brain has two lobes. These are called the **cerebral hemispheres** and are important association centres where



Brain

1. Skull 2. Cerebrum 3. Mid brain 4. Cerebellum
5. Medulla Oblongata 6. Spinal Cord 7. Pituitary Gland

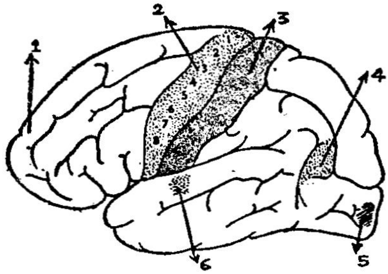
Fig. 67

linkages between thousands of nerve cells allow intelligent behaviour, memory and in ourselves consciousness of our own activities. In animals without cerebral hemispheres, the behaviour is a matter of simple and conditioned reflexes and inborn behaviour patterns called instinct.

Certain regions of the cerebral hemispheres have been formed to effect certain regions of the body or concerned with impulses from a particular sense organ. The cerebral part of the brain receives impulses from all sensory organs and sends out motor impulses to the glands and muscles causing them to function accordingly.

It correlates to its association centres the various stimuli from the different sense organs.

The association centres and motor areas are responsible for coordinating the bodily activities, hence making it possible for the mechanism and chemical reactions of the body work efficiently together.



Sensory Area of the Brain

1. Front Lobe 2. Motor Area 3. Sensory Area
4. Eye Muscles 5. Sight 6. Hearing

Fig. 68

The **cerebrum** stores information so that behaviour can be modified according to past experience.

The right and left hemispheres of cerebrum controls the organs of the left half and right half of the body respectively.

The brain is protected by three membranes called **meninges** in addition to the cranium.

In the hind part of the cerebrum is the **cerebellum,** lying below. It also has two lobes connected by the nerve fibres. It controls and coordinates all muscular movements of the body and the balancing organs that make precise and accurate movements possible. That is why when it is affected by alcohol, the movement of the drunkard seems to have less coordination.

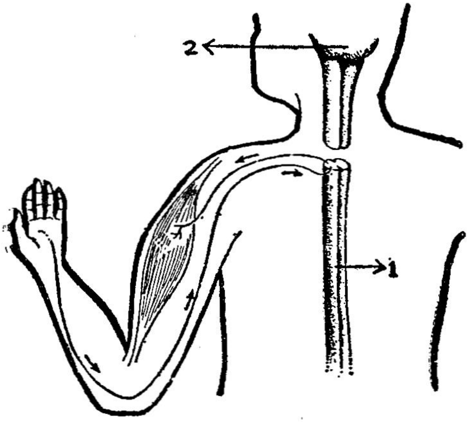
Medulla oblongata is the bottom most part of the brain. Many involuntary functions of the body like respiration and heart beat are under its control. That is why any shock given to this part proves fatal.

Next comes the **spinal cord** which consists of a great number of nerve cells both fibres and cell bodies grouped

into a cylindrical mass running from the brain to the tail end of the spine. It is protected by the spinal column. In between the vertebrae, the spinal nerves run to all parts of the body. There are 31 pairs of spinal nerves. These nerves carry the sensory impulses to the brain, to the muscles and other organs of the body and are concerned with spinal reflex. The nerve cell bodies are grouped in such a way in the centre that a roughly '*H*' shaped region of grey matter is found. Outside this is the white matter.

Reflex Action

Reflex action is the rapid automatic response to a stimulus by an organ or system of organs which does not involve the brain for its initiation.



Reflex Action
1. Spinal Cord 2. Brain
Fig. 69

Reflex Action
1. Affarent Nerve
2. Efferent Nerve
3. Inner zone of Spinal Cord-Grey Matter
Fig. 70

The iris of the eye can contract or dilate the pupil in response to changing light intensity without our being aware

that it is happening. Generally we are aware of a reflex occuring but are unable to control it. We blink when a foreign particle touches the cornea. It is a reflex action which protects the eyes. Though we know it is happening, we are unable to prevent it or modify it. Sneezing is a reflex response to some stimulus in the nose. If the right leg is crossed over the left and struck sharply just above or below the knee cap, the lower leg jerks outwards. If one unexpectedly touches a hot object, the hand is rapidly removed from the source of heat. Heat or pain receptors in the skin are stimulated and the impulses which travel along the sensory fibres in a nerve of the arm. The sensory fibres enter the spinal cord. In the grey matter of the spinal cord the impulses pass from the sensory fibre to a relay or association neurons across a synapse. The relay neuron in turn makes a synapse with one or more motor fibres. The impulses are then transmitted to the motor fibres which leave the spinal cord through the ventral root and pass in a nerve probably the same in which the sensory impulse travelled to a muscle, which contracts removing the hand from the painful stimulus caused by heat and preventing damage to the tissues.

The term spinal reflex refers to reflex action in regions below the head and in an animal such as frog spinal, reflex action will occur even if the brain is destroyed. Reflex actions concerning organs of the head take place in the brain. This is called the **cranial reflex.**

Conditioned Reflex

The smell and taste of food is a stimulus that motivates a dog's salivary glands making its mouth water. **Pavlov**, a Russion biologist carried out many experiments with dogs on conditioned reflexes. For many days Pavlov rang a bell at the time the food was given to the dog.

Later the sound of the bell alone was a sufficient stimulus to cause the dog's mouth to water without sight or smell of the food. The original chemical stimulus of the food had been replaced by an unrelated stimulus through the ears.

The training of many circus animals is done largely by conditioning them to respond to new

stimuli. Our walking and riding a bicycle, typing are complicated sets of conditioned reflexes which we acquire in the first place by conscious concentration and practice.

Questions

1. What are neurons ?
2. What are nerve fibres?
3. What is the special property of nerve fibres?
4. What are afferent and efferent nerves ?
5. What is a synapse?
6. Describe the human brain with the help of a diagram.
7. What is the function of the cerebrum?
8. Why does the movement of a drunkard have less co-ordination?
9. Any shock given to medulla oblangata proves fatal. Explain.
10. What is reflex action?
11. Explain with the help of a diagram how the spinal reflex happens.
12. Explain what is meant by conditioned reflex.

11. SENSORY ORGANS

Skin has a great number of sensory organs fairly and evenly distributed throughout its surface covering the entire body. Generally a particular sense organ or sense cell can respond to only one type of stimulus. A sense organ sensitive to heat will not be affected by the stimulus of touch. A cell which is sensitive to chemicals will not respond to pressure. Yet in the case of pain revealing sensory endings which produce the sensation of pain, they can be activated by a variety of stimuli such as pressure, heat and cold.

Certain regions of the skin have a greater concentration of sense organs than others, eg. the finger tips. They have a large number of touch organs which are particularly sensitive to touch. The front of the upper arm is sensitive to heat and cold. Some areas of the skin have relatively few sense organs and can be pricked or burnt in certain places without any sensation being felt.

The sense cells of a sense organ are connected to the brain or spinal cord by nerve fibres. When the sense organ receives a suitable stimulus, it sets off an electrical impulse which travels along the nerve fibre to the brain or the spinal cord. When it reaches the brain, we come to know the nature of the stimulus and where it is applied. The spinal cord may cause a reflex action before the brain is aware of it.

The different kinds of sense organs are connected to different regions in the brain. It is the region of the brain to which the impulse comes and gives rise to the knowledge about the nature of the stimulus and the place from where it is received.

The impulses that are transmitted along the nerve fibres are all fundamentally alike. It is not the sensations themselves, that are carried out but simply a surge of electricity and this is so whether it is the heat organ or the touch organ that sets off the impulses. It is only in the brain that the stimulus is identified, according to the region of the brain which the impulse enters.

The intensity of sensation is proportional to the greater number of sense organs or cells in the area and their response to stimuli. Vigorous stimulation does not alter the quality or intensity of the electrical impulse travelling in the nerve fibres but increases the total number of these impulses reaching the brain.

The sensation of pain, though not welcome, helps to avoid the damage to tissues by reflexes as in touching hot objects. It also helps us to avoid certain situations. When pain occurs without producing a reflex action as in tooth ache, it serves

as a warning that something has gone wrong to a particular region and gives us an opportunity to seek medical advice and treatment.

Internal sense organs are found within the muscles and tendons. Sensory pain endings occur in many internal organs but not in the brain.

Sight, hearing and balance, smell and taste are called the special senses and the eyes, ear, nose and tongue are the special sense organs.

Each special sense organ consists of a great concentration of cells which are sensitive to one kind of stimulus.

On the tongue, groups of sensory cells are found that can be stimulated by chemicals which dissolve in the moisture overlying them. These groups are called **taste buds.** They lie mostly in the grooves round the bases of the little projections on the upper surface of the tongue. The taste buds are of four kinds. They respond to groups of chemicals which we describe as sour, sweet, salt or bitter. This sense of taste is very limited and helps us to distinguish between foods suitable and unsuitable for eating.

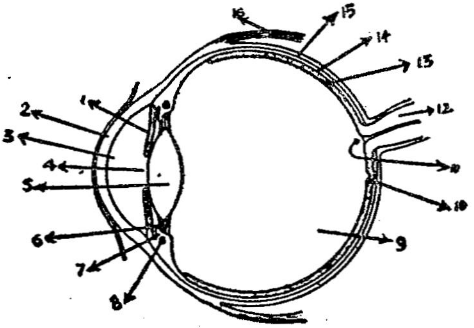
The sensation of flavour comes from the sense of smell. In the tissue lining of the top of the nasal cavity there are spindle-shaped cells with processes extending out into the mucus film that spreads over the tissue. From these cells, nerve fibres pass into the brain. The cells are stimulated by substances which dissolve in the moist lining of thin region of the nasal cavity and hence produce the sensation of smell.

The sense of smell, experienced for a long time, ceases to give any sensation and we become unaware of it though a new comer may detect it at once.

The Eyes

The eyes are the organs of sight. They are spherical organs housed in deep depressions of the skull, called orbits

and are attached to the wall of the orbit by six muscles which can also move the eyeball.



Structure of the Eye

1. Iris 2. Cornea 3. Aqueous Humour 4. Pupil
5. Lens 6. Suspensory Ligament 7. Ciliary Body
8. Ciliary Muscle 9. Vitreous Humour 10. Fovea
11. Blind Spot 12. Optic Nerve 13. Retina 14. Choroid coat
15. Sclerotic Coat 16. Rectus Muscle

Fig. 71

External Structure

The two lids that cover and protect the eye are called **eye lids.** Closing the eyelids can be voluntary or reflex action. Regular blinking serves to distribute fluid over the surface of the eye and prevents its drying up.

A thin epithelial tissue which lines the inside of eyelids, and continues across the front of the eyeball where it is transparent in the **conjunctiva.** Under the top eyelids, the tear glands open. They secrete a solution of sodium hydrogen carbonate and sodium chloride and keep the exposed surface of the conjunctiva and **cornea** moist. They also wash away dust and other particles. Any enzyme that is present in tear fluid has a destructive action on bacteria. Tear in excess is drained into the nasal cavity through the **lacrymal duct,** which opens at the inside of the cornea of the eyes.

The eye ball is made up of three layers-the **sclerotic. the choroid** and the **retina.**

The sclerotic is a tough, non-elastic fibrous coat round the eye ball.

The choroid is a layer of tissue lining the inside of the sclerotic containing a network of blood vessels supplying food and oxygen to the eye. It is deeply black, so as to reduce the reflection of light within the eye.

Next layer is called the retina which is sensitive to light. There are two kinds of light-sensitive cells called **rods** and **cones**. Cones are sensitive to coloured light and rods are responsive to light of low intensity. The nerve fibres from these cells pass across the front of the retina and all leave at one point to form the optic nerve which passes through the skull into the brain.

In the region where the nerve fibres leave the eye to enter the optic nerve, there are no light sensitive cells. That is called the **blind spot.**

There is a depression in the centre of the retina. It is called the **fovea.** It is the region with the greatest concentration of sensory cells and therefore gives the most accurate interpretation of images. Only here, the form and colour of the image is appreciated in greater detail.

The Vitreous Humour

Within the eyeball, there is a solution of salts, sugars and proteins in water. This liquid helps to refract the light coming into the eye ball and produce an image on the retina. Its pressure on the sclerotic coat maintains the shape of the eye. Next is the crystalline lens which is held in position by the fibres of the suspensory ligament attached to the **ciliary body.**

The ciliary body in the thickened edge of the choroid is the region round the lens. It contains blood vessels and muscle fibres. This consists of an opaque disc of tissue. It is continuous with the choroid at its outer edge. In the centre, there is a hole, called the **pupil,** through which light passes to produce an image on the retina. It has got opposing sets of circular and radial muscle fibres. The contraction or relaxation of these muscle fibres in the **iris** increases or decreases the size or the

pupil. Accordingly the intensity of light entering the eye is controlled. The iris contains a pigment layer that determines the colour of the eye. Blue eyes have no pigments. It also contains blood vessels. The cornea is a transparent disc. It is the front part of the sclerotic and is in front of the iris. It has a curved surface. So when light passes through it, it is reflected and the rays begin to converge. It has within a liquid called **aqueous humour** which also helps in refraction.

The conjuctiva is a thin layer of epithelium. It lines the inside of the eyelids and continues across the front of the eyeball, the transparent cornea.

Image formation and Vision: Light rays, reflected or deflected by external objects, enters the eye through the cornea which is a curved surface and pass through the pupil into the bi-convex lens which focuses them through the vitreous humour on the retina so that the points of light from the

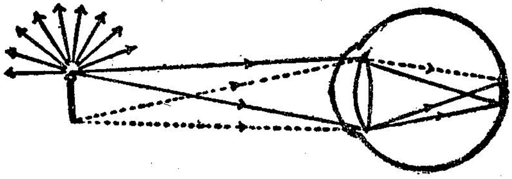


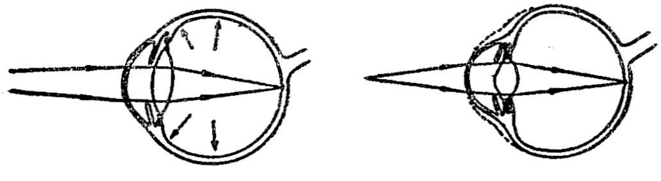
Image formation in the Retina
Fig. 72

object produce points of light on the retina and an inverted image is formed. The light sensitive cells are stimulated by the light falling on them and impulses are fired off in the nerve fibres. These impulses pass along the optic nerve straight to the brain. There an impression is formed on the nature, sizer, colour and distance of the object. In the optical centre of the brain, the inversion of image on the retina is connected to form the impression of an upright object. The accuracy of the impression that the brain gains of the image depends on the number and close packing of the light receiving cells.

Accommodation of the Eye

When the eye is at rest, the lens is thin and has a long focal length and is adapted for seeing distant objects. When an object is nearby, to observe it properly, the lens is made to

become thicker by the contraction of the ciliary muscles which reduce the diameter of the lens. A thicker lens has a short



(a) Eye relaxed (distant accommodation)
(b) Eye focused on near object
Fig. 73

focal length and light from a close object can be brought to a focus. Relaxation of the ciliary muscles allows the fluid pressure acting on the sclerotic to pull the lens back into shape.

When we look at bright light, the intensity of light may cause damage to the retina. So in order to protect the retina, a reflex action happens. The circular muscles of the iris contract and the size of the pupil is reduced and so less light is admitted. When the light is poor, the radial muscles contract and the pupil is widened and more light is admitted which increases the brightness of the image.

Colour Vision

There are three types of cones in the retina. They are sensitive to red, blue and green light respectively. The light waves have different wavelengths. The cones are stimulated by their own particular wavelength of light. According to their numbers and kinds, the brain receives the impression of colour. Among the mammals, only man, monkeys, apes and lemurs can appreciate colour. The others see only black, white and shades of grey.

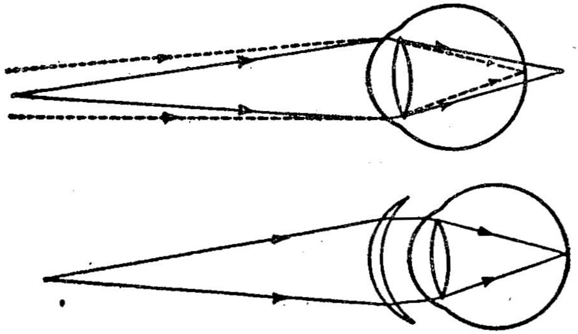
Stereoscopic Vision

Though each eye forms its own image of an object, the brain correlates these so that we gain a single impression of the object. The combination of the two images produce the sensation of solidity and the three dimensional properties of the object. If the two sensory impressions from the eyes are

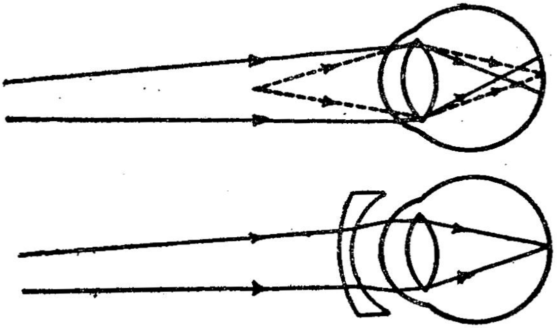
not properly correlated, either due to improper alignment or vision centre being dulled by alcohol, we see double. The stereoscopic vision helps us to judge distance also. The fields of vision for man is 200° yet only objects included in an angle of 2° from the eye will form an image on the fovea.

Long Sight and Short Sight

Long sight is caused by small eye balls or weak lenses. Short sight is usually caused by large eye balls. Light from



1. Eye-Long Sight
2. Long Sight rectified by Convex Lens
Fig. 74 (a)



1. Eye-Short Sight
2. Short Sight rectified by Concave Lens
Fig. 74 (b)

a distant object is brought to a focus on the retina but light from a close object is brought to a focus only behind the retina for a man having long sight. For a man of short sight light from a distant object is focussed in front of the retina.

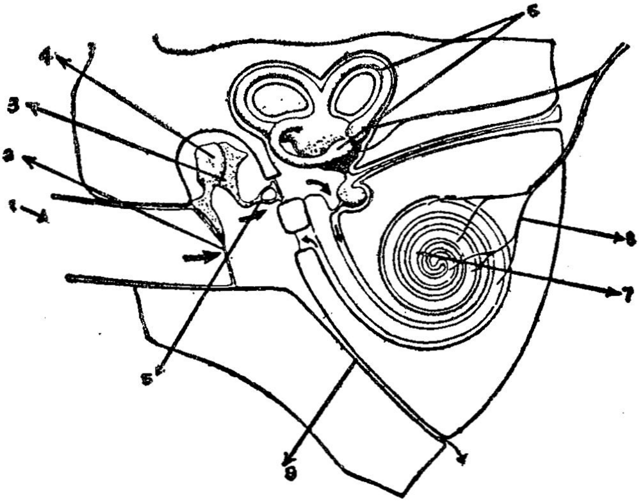
Long sight can be corrected by converging lenses. Short sight can be corrected by divergent lenses.

The Ear

The ear is sensitive to sound vibrations in the air in the range between the frequencies of $30 H_z$ and $30,000\ H_z$.

Structure: The outer ear is made of cartilege and skin and it is called the **pinna.** In some mammals, this helps to concentrate and direct the vibrations into the ear. A membrane of skin and fine fibres is stretched across the innermost end of the outer ear and it is called the **ear drum.**

The eardrum is linked by three small bones or ossicles to a small opening in the skull, the oval window which leads to the inner ear. The air filled cavity in the skull in which the three bones namely **malleus, incus** and **stapes** are found is the middle ear. This cavity is communicated with the back of the mouth cavity through a narrow tube called **eustachian tube.**



Structure of the Ear

1. External Auditory Meatus 2. Tympanum 3. Incus 4. Malleus 5. Stapes 6. Semicircular Canal 7. Cochlea 8. Auditory Nerve 9. Eustachian Tube

Fig. 75

The inner ear consists mainly of a coiled tube, the cochlea, which is filled with a fluid with sensory endings in it. The

sound vibrations are received here and converted into nerve impulses.

When sound waves enter the outer ear, they dash against the ear drum which is set vibrating. This vibration is transmitted through the ossicles which act as levers and cause the innermost of them, the stapes, to vibrate against the oval window. The ear drum is greater in size than the oval window. The largeness of its size and the lever action of the ossicles result in an increase of about 22 times the force of the vibrations that reach the inner ear.

The oscillation of the stapes set the fluids of the inner ear, the endolymph vibrating particularly in the cochlea which has got a membrane made up of short and long transverse fibres. The short ones respond to high frequency vibrations and the long ones to low frequency vibrations and the continuous range of intermediate fibres respond to other frequencies. When the fibres vibrate, they stimulate the sensory cells resting upon them, which will send impulses through the auditory nerve to the brain, which distinguishes the difference in the pitch.

Questions

1. To which part of the body are all the sense organs connected?
2. Where is the stimulus to a sense organ identified?
3. What does the intensity of sensation depend on ?
4. How does the sensation of pain help us?
5. Which are the special senses and which are the special sense organs?
6. What are taste buds and where are they found?
7. How is the sensation of smell produced?
8. With the help of a diagram describe the structure of an eye.
9. Which part of the eye is sensitive to light?
10. How is the intensity of the light entering the eye controlled?
11. Explain how an image of an outside object is formed in the retina.
12. How do we get the sensation of vision?

13. What are the causes of long sight and short-sight and how can they be corrected?
14. What are the different parts of the ear?
15. How does the vibration in the air outside reach our inner ear? How do we get the sensation of hearing?

Learn this

Eye : An eye defect known as **cataract** results in the lens becoming opaque. To relieve the condition, the lens can be removed completely. What disadvantages would result from such an operation ?

Ear : A person whose ear ossicles are ineffective can often hear a ticking watch pressed against his head better than he can if it is held close to ear. Explain this effect.

12. PARENTAL CARE

Parental care is protection of the young ones by the parents till they can take care of themselves. This may be done by feeding and direct nursing or by means of nest or nurseries.

The young ones are to be protected from heat and cold and from enemies. Man, monkey, lion, tiger, elephant and other animals belonging to the group of mammals, birds, and fish and other lower vertebrates show parental care.

Protection by means of Nests and Nurseries

A fresh water fish by name **Gourami** builds a nest with reeds and the female lays the eggs inside. The male fertilises them and then both the male and female parents guard the eggs and protect them till they are hatched and the young ones grow big enough to be able to feed for themselves.

A fish called **sea horse** or **Hippocampus** shows parental care. The male is provided with a brood pouch in the abdomen. The fertitised eggs are placed in the bag like structure until they are fully developed into baby hippes. This is a fine example of a male animal, taking care of the eggs.

A large tree frog in Brazil protects the progeny by building a basin shaped nursery in shallow water on the border of the pond. The eggs and early larvae are thus protected from

attack of many insects and fishes for some time till heavy rains later on destroy the wall and the larvae go to the water.

The eggs of another type of frog are enclosed in a transparent bag of gelatinous membrane secreted by the female and the bag is left in the mountain streams. The whole development takes place within the eggs and little frogs come out in perfect condition.

Some tree frogs in South America, Africa deposit their spawn on trees in nests of froth attached to one or many leaves stuck together and overhanging a pool for a few days. The larvae move in the froth and after losing their external gills, they fall in water to complete the metamorphosis.

Some South American frogs carry well developed tadpoles on their back from one pool to another particularly when one pond is to dry up. Some male frogs carry the eggs round the legs.

A kind of frog called **midwife toad** winds the string of eggs round its posterior body and thighs and buries itself in the moist earth. It makes occasional trips to water to keep the eggs wet. When tadpoles are in an advanced stage and ready to hatch, the male plunges itself into water, where tadpole larvae hatch and undergo metamorphosis. This is found in France and Italy.

The **flying frog** also exhibits parental care by depositing eggs in the nest near water.

The parental care is well developed in birds which build nests for laying eggs and to protect them from enemies. They sit on eggs for days and hatch the eggs when the young one comes out of the mother bird and feed them until such time they can fly and find their own prey. Pigeons, crows, hens are good examples. Normally, the female bird sits on the eggs. But the eggs of ostrich are incubated by the male.

The mammals which are at the top of the animal kingdom exhibit the parental care in a greater measure than all other animals. The females have the milk glands which produce milk for the nourishing of the young for some time after birth. The calf is nourished by the milk of the cow. How cats, dogs, pigs

feed their young ones with the milk is a common sight. The human mother also feeds the child with her milk, but the parental care she exhibits has no equal in the world.

Questions

1. What is parental care?
2. Name some animals which show parental care.
3. How does gourami fish show parental care?
4. How does hippocampous show parental care?
5. How do some frogs in South America and South Africa show parental care?
6. In what ways do the birds show better parental care than frogs and fish?
7. Describe how mammals show greater parental care and among them man the greatest.

13. METAMORPHOSIS

The young ones of hen or duck or other birds come out when the eggs are hatched. They look exactly like the parent birds but are very tiny in size.

The young ones that come out of the eggs of certain animals and insects do not look like the parents. They look like worms. Gradually they grow and undergo many changes and after some time attains the shape and the qualities of the parents.

When the eggs are hatched, the tadpoles come out. They undergo a series of changes which transform them into a young frog. The changes that take place from the egg stage to the adult stage are called metamorphosis.

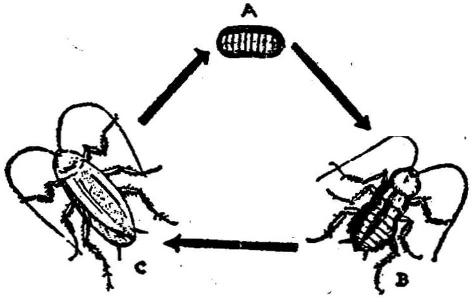
Three kinds of metamorphosis are observed among insects and animals. (1) **Direct growth** (2) **Incomplete metamorphosis** (3) **Complete metamorphosis.**

Direct Growth

We commonly see some small soft silvery white insects. They have small legs and segmented abdomen. Gradually they grow into adults. So the direct growth is seen here.

Incomplete Metamorphosis

The **cockroach** lays eggs in a tiny purse like case in two rows of eight each and is placed in a safe place. The young



Life History of Cockroach
A. Egg B. Nymph C. Adult
Fig 76

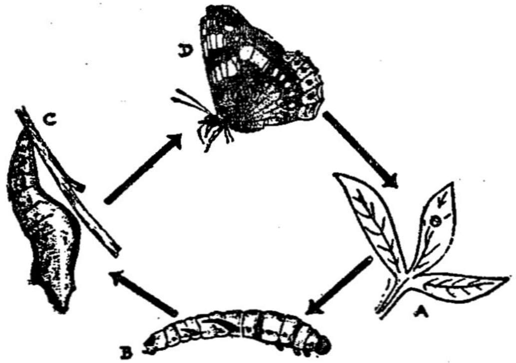
ones come out of the eggs after a time. They look like the adult; but with some difference in size and colour, and without wings and reproductive organs. This young one of the cockroach is called the **nymph**. When this grows, its outer covering is cast off by a rupture at the back. The removal of outer covering this way is called **moulting** or **ecdycis**. This happens seven times before the nymph becomes an adult cockroach, when it develops wings and genital organs. It takes about nine months for this metamorphosis in the nymph. The type of metamorphosis is called incomplete metamorphosis, which can be observed in the *grasshopper* and *dragonfly*.

Complete Metamorphosis

The series of changes that happen from the egg stage to the adult stage in the life of *butterfly* or *a silk moth* or *mosquito* are examples of complete metamorphosis. The beautiful butterfly that attracts us with the fluttering of its wings lays the eggs on the lower surfaces of the leaves. The eggs

get attached to the leaves by a sticky secretion from the body of the butterfly. The eggs hatch after a week and tiny worm like things called 'larvae' come out.

These larvae are called caterpillars. A caterpillar has a segmented body and a distinct head. The first three segments



Life History of Butterfly
A. Egg B. Caterpillar C. Pupa
Fig. 77

are the thorax and the last ten are the abdomen. The head has a group of simple eyes on each side and a pair of antennae. The mouth has two jaws and the labium or lip. Near the lip, the spinning glands are seen. They secrete a sticky substance with the help of which the caterpillar attaches itself to the under surface of a leaf after four or five moultings at regular intervals and enters a period of inactivity called the **pupal** stage, without even taking food. The pupal period is about ten to twelve days during which the external and internal structures are reorganized and at last the **imago** emerges with its wings breaking the pupal case. It starts flying and we see the beautiful butterfly with a pair of compound eyes which goes from flower to flower sucking honey with its long **probosis** which is kept coiled like a spring. It has a pair of club shaped antennae.

The period of metamorphosis from the egg stage to the adult stage is about six to seven weeks in the life history of the butterfly.

The life history of the silk moth also is very similar to that of a butterfly. The only difference we note is that the caterpillar spins a cocoon of silk fibre which is the source of silk production.

Questions

1. What are the three kinds of metamorphosis?
2. Describe the metamorphosis that happens in the life history of the cockroach.
3. Describe the metamorphosis that takes place in the life history of a butterfly or silk moth.
4. Observe the metamorphosis that takes places in the life history of a mosquito in stagnant water.

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